EARTHQUAKE HAZARDS REDUCTION ACT

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

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EARTHQUAKE HAZARDS REDUCTION ACT

TUESDAY, MARCH 19, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 1:40 p.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. WALGREN. Good afternoon, ladies and gentlemen. This is an authorization hearing to review the National Earthquake Hazards Reduction Program to see if the program is working at the local, State, and Federal level.

The Earthquake Hazards Reduction Act, which established the National Earthquake Hazards Reduction Program, was passed in 1977 in view of the widespread recognition that earthquake hazard reduction is a very important area of research and investment that we should make as a nation.

Although Earthquake Hazards Reduction Act hazards are associated with relatively finite areas of our country, particularly California, the truth of it is that historically the rest of the country has experienced earthquake events. And our best judgment is that literally 39 States are at risk, an area that presents a risk to nearly 70 million Americans. The risks to life and property are as great now as they were in 1977.

The fact that there has not been a major loss or catastrophe between now and then, as all you know, does not indicate that our efforts should be any the less. In fact, you might say it is 5 years on what may be an unknown time line, but nonetheless a certain time line from a probability standpoint, 5 years less on that time line now than there was in 1977. So it's important that we give every effort that we can to make these programs work.

The infrequency of these kinds of events leads to a feeling of well-being that may not be well placed. And we want to be sure that we are discharging our responsibility to look down the road. It's clear that investments in these efforts in developing the ability to warn the population, large numbers of people, and developing the ability to lessen the loss in the event of a major earthquake can only be considered more than cost effective. The dimension of the loss in both life and property is so large that the effort we make certainly is something that is compelling.

The implementation of this legislation, as those of you involved in it know, is relatively complex, and I think from a governmental standpoint, difficult to appreciate, because it involves the coordina-

tion of so many different levels of our government, both national, State and local, and whenever programs are largely coordinative in nature, they are largely underappreciated because the reality of them, the real benefits of them, tend to be stored away in reports and represented by contacts and relationships that are not necessarily able to be showcased, but nonetheless are important.

And the balance between these levels of society, inasmuch as society must be involved in running with this program, if it's to be effective, it's in those kinds of relationships that real value lies. And the fact that we do not have a product to be put on the shelf is not to say that this isn't the most important effort.

In our authorization hearing 2 years ago we were concerned about the status of the Federal Emergency Management Agency's 5-year update of the program plan. As I understand it, that plan does now exist, and we hope to review the recommendations that have been recently released and to compare them with recommendations made by others who are knowledgeable in the field whose views we certainly want to take into account.

We also want to review the findings from the National Academy of Sciences' study of the needs and priorities for earthquake engineering facilities and try to bring these two together. We feel it is very important to maintain the momentum that we have made, the start we have made, and the commitment that we have made over these years.

And we want to encourage those in the administration that are involved with the responsibility of executing these plans. When we all turn to other things and go back to our districts, we hope you will go back to your executive agencies and make the progress in this area that the public interest deserves.

[The prepared statement of Mr. Walgren follows:]

OPENING STATEMENT

HON. DOUG WALGREN (D-PA)

HEARING ON REAUTHORIZATION OF THE EARTHQUAKE HAZARDS REDUCTION ACT

MARCH 19, 1985

GOOD AFTERNOON LADIES AND GENTLEMEN. THIS IS AN AUTHORIZATION HEARING TO REVIEW THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM TO SEE IF THE PROGRAM IS WORKING AT THE LOCAL, STATE AND FEDERAL LEVEL.

THE EARTHQUAKE HAZARDS REDUCTION ACT WHICH ESTABLISHED THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM WAS PASSED IN 1977 BECAUSE CONGRESS RECOGNIZED THAT EARTHQUAKE HAZARD MITIGATION IS A WISE NATIONAL INVESTMENT.

ALTHOUGH EARTHQUAKE HAZARDS ARE POPULARLY ASSOCIATED WITH CALIFORNIA, IN FACT, ALL OR PORTIONS OF 39 STATES ARE AT RISK. WITHIN THESE BOUNDARIES LIVE 70 MILLION PEOPLE. THE RISKS TO LIFE AND PROPERTY ARE AS GREAT NOW AS WHEN THE BILL WAS PASSED, AND THE NEED FOR A COORDINATED NATIONAL APPROACH IS EQUALLY GREAT.

THE INFREQUENCY OF CATASTROPHIC EVENTS, SUCH AS EARTHQUAKES, TENDS TO PRODUCE AN ATTITUDE OF NEGLECT. IT IS THE RESPONSIBILITY OF CONGRESS TO INSURE THAT NEGLECT OF THIS PARTICULAR LEGISLATION DOES NOT OCCUR. INVESTMENT IN MEASURES TO WARN OF AND REDUCE THE EFFECTS OF EARTHQUAKES CAN BRING GREAT SAVINGS IN LIVES, IN RECOVERY, AND IN COSTS OF REPAIR LATER ON.

IMPLEMENTATION OF THIS LEGISLATION IS VERY COMPLEX, SINCE IT INVOLVES COORDINATION BETWEEN FOUR FEDERAL AGENCIES, AS WELL AS STATE AND LOCAL GOVERNMENTS. EACH OF THESE HAS A SPECIFIC RESPONSIBILITY AND SPECIFIC DUTIES, AND MAINTAINING BALANCE BETWEEN THEM IS ESSENTIAL FOR THE EFFECTIVE OPERATION OF THE PROGRAM.

IN OUR AUTHORIZATION HEARING TWO YEARS AGO, THE SUBCOMMITTEE WAS CONCERNED ABOUT THE STATUS OF FEMA'S FIVE-YEAR UPDATE OF THE PROGRAM PLAN FOR THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM. THE SUBCOMMITTEE NOW PLANS TO REVIEW THE RECOMMENDATIONS IN THE RECENTLY RELEASED, PROGRAM PLAN. WE WANT TO COMPARE THE PLAN WITH RECOMMENDATIONS MADE BY AN INDEPENDENT PANEL OF EXPERTS.

ALSO, WE HOPE TO REVIEW THE FINDINGS FROM THE NATIONAL ACADEMY OF SCIENCES STUDY OF THE NEEDS AND PRIORITIES FOR EARTHQUAKE ENGINEERING FACILITIES AND INSTRUMENTATION IN THE U.S.

IT IS IMPORTANT TO MAINTAIN BOTH THE MOMENTUM AND FEDERAL COMMITMENT TO THE NATIONAL PROGRAM. THIS HEARING WILL SEEK TO EVALUATE THE ADMINISTRATION'S PROPOSALS IN THAT LIGHT.

I LOOK FORWARD TO HEARING THE TESTIMONY OF THE WITNESSES.

Mr. WALGREN. So, with that, I want to welcome you to the committee. As ground rules, your written statements will be made part of the record without more, and they will be reproduced in full for the review of those interested in this area, the committee, the committee staff, and the public. If you would proceed to outline the points that you feel are really worth underscoring in whatever way you feel is best to communicate to the record, we would certainly appreciate that.

The first panel is made up of: Dr. Samuel Speck, the Associate Director of State and Local Programs and Support for FEMA; Dr. Dallas Peck, the Director of the U.S. Geological Survey, who is accompanied by Dr. John Filson, who is with the Office of Earthquakes, Volcanoes, and Engineering of the Geological Survey.

Also on the panel is Dr. Nam Suh, the director of engineering at the National Science Foundation; Ray Kammer, Deputy Director of the National Bureau of Standards, also accompanied by Dr. Richard Wright, who is the Director of the Center for Building Technology at the Bureau.

Gentlemen, welcome to the committee. We appreciate being here. Let's start with Dr. Speck.

STATEMENT OF DR. SAMUEL W. SPECK, ASSOCIATE DIRECTOR, STATE AND LOCAL PROGRAMS AND SUPPORT, FEDERAL EMERGENCY MANAGEMENT AGENCY

Dr. SPECK. I am pleased to appear before this session of the House Committee on Science and Technology, Subcommittee on Science, Research and Technology to present the Federal Emergency Management Agency's comments on the National Earthquake Hazards Reduction Program in connection with the reauthorization of the Earthquake Hazards Reduction Act of 1977.

In these remarks I will summarize my testimony, which is being submitted in its entirety for the record. In my oral testimony I would like to do three things: First, briefly summarize the activities and allocation of responsibilities under the National Earthquake Hazards Reduction Program; second, summarily describe FEMA's responsibilities within the program; and third, briefly detail fiscal year 1985 and projected fiscal year 1986 FEMA outputs under the program.

Simply put, the Earthquake Hazards Reduction Act of 1977's purpose is the reduction of risks to life and property in the United States from future earthquakes. In creating the National Earthquake Hazards Reduction Program, Congress brought together the earthquake hazard-related research programs already underway of the U.S. Geological Survey, the National Science Foundation, and the National Bureau of Standards with the activities of FEMA, to form an integrated and comprehensive Federal program.

These agencies constitute the four principal agencies of the National Earthquake Hazards Reduction Program. Congress has designated FEMA as the lead agency for the program, with responsibility for developing, leading, and coordinating the program. As such, FEMA chairs a variety of interagency coordinating mechanisms at both the senior policy and program manager levels. These have proven to be effective in dealing with the range of issues the

program faces. FEMA oversees and coordinates the preparation and submission on behalf of the President of the program's annual report to Congress each year.

FEMA also has submitted to Congress on behalf of the administration proposed legislation to reauthorize appropriations under the Earthquake Hazards Reduction Act totaling $68,899,000 for fiscal year 1986 and sums as may be necessary for fiscal year 1987. This legislation basically freezes the total authorized amount under the Earthquake Hazards Reduction Act at the level approximating that authorized for fiscal year 1985.

Working through the interagency coordinating mechanisms, FEMA has prepared the 5-year plan for the program which is required by the act. It was transmitted to Congress on January 4, 1985, and outlines the programs of the principal agencies in carrying out their responsibilities. The time period covered by the plan includes fiscal years 1985 through 1989.

This plan translates the purpose and objectives of the Earthquake Hazards Reduction Act into a program consisting of five major elements and outlines specific goals and objectives for each element. These elements, which I will now briefly discuss, are listed on your left of the right-hand chart.

You will notice that that chart lists five basic elements starting with No. 1, hazard delineation and assessment. You will notice it breaks that down into subparts shown and on the right-hand side of the chart that indicates which agency is primarily responsible for that activity.

First, we have hazard delineation and assessment, or, "What do earthquakes do?" Second, earthquake prediction research. Third, seismic design and engineering research. Fourth, preparedness planning and hazard awareness—in other words, public education insofar as hazard awareness is concerned. And finally, fundamental seismological studies, that is, what causes earthquakes.

FEMA has submitted legislation which would change the current requirement for an annual update of the 5-year plan to updates as necessitated by events or at least every 5 years. The reasons for this change are the process of preparing the plan is time- and staff-consuming, and we anticipate that an annual update would require substantial resources, while programmatic activities in this area are usually undertaken on a multiyear cycle; therefore, an annual update would be inappropriate.

FEMA, through the submission to Congress of the annual report, will continue to report regularly on the progress being made by the agencies to accomplish the objectives in the 5-year plan. And I want to distinguish between the annual report which would continue to be presented annually and the annual update of the 5-year plan.

In terms of FEMA's Earthquake Program activities, as in all matters related to the public health and safety, state and local governments bear the primary responsibility for the protection of life and property in the event of a serious or catastrophic earthquake. They and individuals in the private sector are also the ultimate users of information generated by the program.

To assist State and local governments to enhance their overall emergency management capabilities, FEMA has developed the In-

tegrated Emergency Management System, or IEMS, as depicted on the chart on the right. IEMS stresses the preparedness elements common to emergencies across the spectrum while at the same time recognizing elements unique to specific types of emergencies.

Guidance for the implementation of the IEMS approach was developed in 1983, field tested in 1984, and is undergoing full field implementation with automatic data processing capability in 1985. The IEMS functional approach to comprehensive emergency management was funded last year by approximately $100 million in civil defense funds through direct program and training support to State and local governments.

I think that is an important aspect of the overall program, Mr. Chairman, in the sense that we are not only building capability as it relates specifically to earthquakes, but also building a generic capability, from which the earthquake programs benefit as do all other hazard-related programs, whether it be hurricanes or dam safety or flood control or the like.

Under the Earthquake Program, FEMA has responsibility for five areas of activity in addition to its leadership role. FEMA conducts these activities within the framework provided by IEMS.

I will now briefly discuss the elements of FEMA's Earthquake Program in terms of past accomplishments and planned activities for the future. To assist the committee, you will note that we have two charts: the one on the right indicating our expected program accomplishments for fiscal year 1985, and the one on the left projecting our expected accomplishments in fiscal year 1986.

In the area of seismic design and construction standards, the partial or total collapse of structures is the main cause of earthquake injuries and deaths. However, casualties can occur not only from the buildings themselves but from the secondary effects of failed lifelines, such as fires caused by ruptured natural gas lines. In order to lessen these threats over the long term, FEMA supports activities which can enhance the seismic safety of new and existing buildings as well as lifelines.

The Interagency Committee on Seismic Safety in Construction has prepared and issued a draft seismic safety standard for new Federal buildings which is currently being updated and balloted by the Federal agencies. FEMA is presently focusing on ways to ensure a wide acceptance and application of this standard.

With respect to new non-federal buildings, a multiyear effort by the Building Seismic Safety Council, under a contract with FEMA, has resulted in the publication of the National Earthquake Hazards Reduction Program Recommended Provisions For The Development of Seismic Regulations for New Buildings, in draft form.

Final balloting of this document by the Building Seismic Safety Council member organizations is now scheduled for the fall of 1985. These provisions will be available for use by code groups, State and local governments, and the design professions.

Late last summer FEMA contracted with ABE—which is a joint venture of the Applied Technology Council, Building Seismic Safety Council, and the Earthquake Engineering Research Institute—for the development of a comprehensive and detailed plan to address the seismic vulnerability of existing buildings. This plan is expected to be ready by the end of fiscal year 1985. Fiscal year 1986 funds

will be used to start the most urgent and high-priority items identified in this plan.

During this spring, FEMA plans to contract for a long-range plan on how to enhance the seismic safety of new and existing lifelines. This plan is not expected to be ready before the end of fiscal year 1986, with implementation, therefore, extending into the outyears. Due to the complexity of the issues surrounding lifelines, this area of seismic design promises to be one of the most challenging tasks in future years.

Regarding State and local hazards reduction, major objectives of the program include developing means of reducing the risks from earthquakes, providing warnings of earthquakes, organizing State and local emergency services, and planning for the reconstruction and redevelopment after an earthquake. Twelve areas of high population, high earthquake risk, have been identified, and in fiscal year 1985, for the first time, FEMA is supporting earthquake hazards reduction projects in all 12 of them. The 12 areas are: Anchorage, AK; Puget Sound, WA; southern California; northern California; Honolulu, HI; Salt Lake City, UT, Central United States; Charleston, SC; Boston, MA; New York State; Puerto Rico; and the Virgin Islands.

These areas are all at various stages in implementing their earthquake programs. Some of them are at a relatively early stage of vulnerability assessment while others are involved in preparedness and response planning and mitigation and Federal response activities. You will find a detailed statement with respect to each of these 12 areas on pages 13 through 16 in my prepared testimony.

With the program's expansion to all high-risk areas, FEMA recognized the importance of developing a standardized earthquake loss estimation methodology for use throughout the entire Nation. We plan to initiate this effort this year.

Currently, FEMA is completing work on a formal civil preparedness guide which describes the tasks and activities that comprise a balanced State or local Earthquake Hazards Reduction Program. It is expected to be available for use in planning fiscal year 1986 projects. This guide is a major advance in the availability of earthquake program guidance.

In the area of Federal response planning, State and local resources will be inadequate to respond to a catastrophic earthquake. Response from the Federal Government, both from the local geographic area and from the entire Nation, will be required. Therefore, in recognition of the increasing threat of a catastrophic earthquake in California as well as the possibility of catastrophic earthquakes in other areas, FEMA initiated a response planning effort that involves the entire Federal Government.

The third draft of the resulting Federal response plan was reviewed at a tabletop exercise in Response 1984, which was based on a simulated catastrophic earthquake on the southern San Andreas Fault. The lessons learned from Response 1984 were incorporated into the fourth draft of the plan, which will be field tested in Response 1985 in June 1985 in California. Future work will initiate development of Federal regional plans and include exercises to maintain and update the national plan.

In the area of mitigation in multihazard preparedness planning, until now earthquake preparedness planning has been conducted

with an exclusive concentration on reducing seismic risk. However, earthquakes also trigger multiple and simultaneous disasters, such as fires, floods from ruptured dams, landslides, and toxic spills. For areas where earthquake reoccurrence periods are long and current seismicity is low, earthquake preparedness measures may be politically and economically feasible only if they are combined with those to reduce other hazards.

A multihazard approach to planning is underway in Ogden, UT, to assess the combined risks from seismic hazards, dam failure, and floods. This effort is expected to provide cost-effective and manageable preparedness strategies and recommendations for short-term mitigation of existing hazards and long-term land use planning to avoid them. The project should be completed next year, at which time its transferability will be assessed.

Mr. Chairman, I had the opportunity of spending time in Utah this past week and going up to look at what is being done under that particular project.

The banking and insurance industries are the subject of consideration with respect to earthquake hazard mitigation because of the critical functions they perform in our society. FEMA is planning to examine them from two points of view: As agents for bringing about abatement of seismic risks through their loan, insurance, and related practices; and as institutions with the continuing functions which are vital to the restoration of community life after a damaging earthquake. The goal is to reach policy conclusions by the end of fiscal year 1986.

In order for individuals, organizations, and governmental units to most effectively plan for, respond to, and take appropriate recovery and mitigation actions related to earthquake hazards, a comprehensive earthquake education and information transfer program is essential. At the end of fiscal year 1984 FEMA completed the development of a multiyear earthquake education management plan which identifies milestones and expected accomplishments and facilitates analysis, evaluation, and identification of future funding priorities.

FEMA has promoted community outreach efforts through support, since 1983, of two pilot earthquake education centers in Charleston, SC, and Memphis, TN, as well as in a pilot project to reduce the vulnerability of Seattle, WA, school population to the consequences of earthquakes. And, Mr. Chairman, I have examples of some of these, including the prototype for schools with me. In fiscal year 1986 these efforts will be completed and evaluated for transferability.

FEMA has also initiated competitive challenge grants to stimulate local public information demonstration projects, provided a grant to the Children's Television Workshop, producer of TV's Sesame Street, to develop a multihazard program for youth, and initiated a series of emergency information exchanges. Again, I have a number of pieces of the kinds of information that are available.

With the USGS, FEMA sponsors workshops designed to increase the hazard awareness of elected officials and influential public and private policy makers in high-risk areas. Since 1981 some dozen workshops have been held or are now planned. Through the Na-

tional Emergency Training Center, FEMA has developed course entitled "Earthquake Hazard Mitigation for Utility Lifeline," which is the first in a series of special topical courses in hazard mitigation. Other courses will be developed to address such topics as earthquake hazards for high-rise, high-occupancy buildings, and nonstructural earthquake hazard mitigation for hospitals.

Finally, in 1984, the southern California earthquake preparedness project, known as SCEPP, delivered to FEMA the products it had developed since its creation in 1980. FEMA has reviewed these materials to determine their transferability to areas outside of southern California and the most effective means of disseminating them to other areas. We expect to have them available for distribution later this year.

Thank you. This concludes my comments, and I will be glad to answer any questions at the appropriate time.

[The prepared statement of Dr. Speck follows:]

Statement of

Dr. Samuel W. Speck

Associate Director, State and Local Programs and Support

Federal Emergency Management Agency

Before the

House Committee on Science and Technology

Subcommittee on Science, Research, and Technology

March 19, 1985

INTRODUCTION

I am pleased to appear before this session of the House Committee on Science and Technology, Subcommittee on Science, Research, and Technology to present the Federal Emergency Management Agency's (FEMA) comments on the National Earthquake Hazards Reduction Program (NEHRP) in connection with the reauthorization of the Earthquake Hazards Reduction Act of 1977. My discussion today will cover the objectives of the law, FEMA's leadership role in the NEHRP, the roles of other Federal agencies, the Five-Year Plan, the five major elements which comprise NEHRP, and the five major elements of FEMA's earthquake hazards reduction program.

THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

The Earthquake Hazards Reduction Act of 1977 (P.L. 95-124), as amended, has as its purpose the reduction of the risks to life and property in the United States from future earthquakes through the establishment and maintenance of an effective earthquake hazards reduction program. The objectives of the NEHRP include development and improvement of the Nation's capabilities with respect to seismic design and construction; land-use policy decisions and building activity; earthquake prediction techniques and warning systems; coordinated preparedness, response and recovery planning; public education; identification and characterization of the earthquake hazard; and research.

In creating the NEHRP, Congress brought together the earthquake hazard related research programs, already well underway, of the U.S. Geological Survey (USGS), National Science Foundation (NSF), and the National Bureau of Standards (NBS) with the activities of FEMA to form an integrated and comprehensive Federal program.

FEMA'S Leadership Role

FEMA's overall mission is to coordinate Federal emergency management activities (preparedness, response, recovery, and mitigation) for all types of disasters - natural and manmade - and to provide technical and financial assistance to State and local governments in carrying out their emergency management programs. With this in mind Congress designated FEMA as the lead agency for the NEHRP, with responsibility for developing, leading, and coordinating this national program.

FEMA has provided leadership to the program in the following ways:

- FEMA has submitted to the Congress on behalf of the Administration proposed legislation to reauthorize appropriations under the Earthquake Hazards Reduction Act totaling $68,899,000 for Fiscal Year 1986 and sums as may be necessary for Fiscal Year 1987. This legislation basically freezes the total authorized amount under the Earthquake Hazards Reduction Act at a level approximating that authorized for Fiscal Year 1985.

- FEMA has stimulated the creation of the Policy Coordinating Group, composed of senior policy level officials of the four principal agencies (USGS, NBS, NSF, and FEMA), to provide guidance on overall program policy issues and to oversee the NEHRP planning, budget, and evaluation processes. FEMA chairs this important coordinating forum.

- FEMA established and chairs the Interagency Coordinating Committee (ICC) of the NEHRP. The ICC is composed of program-manager level representatives of the four principal agencies assigned responsibilities under the program, and other departments and agencies which conduct earthquake related programs. The ICC provides a setting for the staff to meet regularly and resolve the operational issues facing the agencies in meeting the goals of the NEHRP. The ICC has become, over the past year, stronger than ever.

- FEMA chairs the Earthquake Work Group in support of the Emergency Mobilization Preparedness Board (EMPB). The EMPB was created by the President to ensure that the Nation would be capable of responding effectively to major peacetime and wartime emergencies. The Earthquake Work Group is addressing national mobilization and preparedness issues associated with the consequences of a catastrophic earthquake.

- FEMA has established an Earthquakes and Natural Hazards Programs Division within its Office of Natural and Technological Hazards to provide a focus for earthquake related activities within our agency.

- FEMA, working through the ICC and Policy Coordinating Group mechanisms previously explained, has prepared the Five-Year Plan for the National Earthquake Hazards Reduction Program. The plan, which details the activities to be undertaken by the principal agencies, will be discussed in greater detail below.

- FEMA has continued to promote a strong seismic mitigation program applicable to the Federal community through support of the Interagency Committee on Seismic Safety in Construction (ICSSC). FEMA participates in the ICSSC Steering Committee and provides financial and lead agency support to the National Bureau of Standards, which functions as the Committee's Secretariat. This Committee was nearly dormant two years ago, but since then, largely through FEMA's leadership role, it has been revitalized.

- FEMA chairs the Subcommittee on Federal Earthquake Response Planning of the ICC. This Subcommittee

guides the development of the framework and strategies upon which the National Plan for Response to a Catastrophic Earthquake is based. This plan will be discussed further under FEMA's earthquake program activities.

- FEMA oversees and coordinates the preparation of and submits, on behalf of the President, the NEHRP Annual Report to Congress each year. The law requires that such a report be prepared following each fiscal year, discussing the status of the NEHRP and describing and assessing the progress made during the preceding fiscal year in reducing the risks of earthquake hazards.

The General Accounting Office (GAO), in the latter part of 1982, conducted an evaluation of FEMA's efforts to carry out the lead agency role for the NEHRP, and published a report entitled "Stronger Direction Needed for the National Earthquake Program," in July 1983. The principal recommendation of the Report was to

> ...formalize and strengthen the role of the Earthquake Policy Review Group as the program's oversight and management body by scheduling regular meetings and instituting a process that will bring important issues before it for decision, including establishing program goals, priorities, budgets, and target dates; and requesting, if necessary, specific Congressional funding for its activities.

FEMA responded to this recommendation by having an official charter for the renamed Policy Coordinating Group approved by the members and publishing this charter in the Federal Register on July 20, 1984. FEMA now chairs meetings at approximate six-month intervals and records the agendas, minutes, and follow-up actions. As necessary, meetings may be scheduled more frequently. FEMA also used this group to coordinate the development of the recently completed Five-Year Plan.

An additional recommendation of the GAO evaluators, related to FEMA's lead role, was that the Agency should have a dedicated staff with appropriate technical expertise in order to provide effective leadership for this complex, technical program. Since the report was published, FEMA has improved staff capacity by focusing earthquake program activities in a newly created Earthquakes and Natural Hazards Programs Division (as mentioned earlier). This staff has been free of any reorganizations since November 1983 and the continuity of assignments has allowed staff to develop their professional competence. FEMA also arranged with the USGS for the latter to conduct a course in February 1985 for FEMA's headquarters and regional earthquake program managers and staff on the history, causes, and effects of earthquakes in the United States. Based on the success of this course, future courses on additional subjects may be developed.

Other Participants in the NEHRP

Three agencies have principal roles in the NEHRP, in addition to FEMA. These are the USGS, NBS, and NSF. The USGS conducts basic studies on the nature of earthquakes and their physical processes, hazard delineation and risk analysis, earthquake prediction, and induced seismicity, as well as information dissemination and outreach efforts. The NSF funds basic research on earthquake processes and other fundamental studies, and earthquake engineering research. To supplement FEMA's current staff capacity, the Agency has arranged for and funded the NBS to function as technical monitor on some projects concerning the development of seismic design and construction standards.

In addition to the four principal agencies, there are a number of other agencies that play supporting roles in the NEHRP. These include the Nuclear Regulatory Commission, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, the Veterans Administration, and the Departments of Transportation, Defense, and Housing and Urban Development. In all, there are over twenty agencies that have a role in the NEHRP, stemming at least from their responsibilities in the National Plan for Response to a Catastrophic Earthquake.

The National Earthquake Hazards Reduction Act specifies at several points that the private sector be involved to the extent possible in the various activities of the NEHRP. Elements of the private sector are involved in research and other projects related to the objectives of the NEHRP, and are also often the ultimate users of information produced and disseminated by participating government agencies.

FIVE-YEAR PLAN FOR THE NEHRP

The Five-Year Plan for the NEHRP is required by Section 5 of the Earthquake Hazards Reduction Act of 1977, as amended by P.L. 96-472 of October 19, 1980. The section provides that the Director of FEMA shall "... compile and maintain a written program plan for the program ... which plan will recommend base and incremental budget options for the agencies to carry out the elements and programs specified ... and which plan shall be ... transmitted to the Congress and shall be updated annually...."

Since the inception of the program in 1977, the efforts of NSF and USGS had been guided by an earlier plan published jointly by the two agencies ("Earthquake Prediction and Hazard Mitigation: Options for USGS and NSF Program," September 15, 1976). While providing valuable guidance at the beginning, this plan did not include the efforts of NBS, and FEMA did not yet exist. Further, the report only covered fiscal years through 1980, the limit of the Act's original authorization.

The development and completion of the Five-Year Plan was a longer and more complicated process than anyone involved anticipated

when the effort began. The final Plan was completed and transmitted to Congress on January 4, 1985. An initial plan was developed by the principal agencies and was completed in 1983. Then FEMA convened a panel of 25 experts in a variety of earthquake related fields to provide an independent review of the document. This panel was headed by Karl Steinbrugge, a structural engineer and internationally recognized expert on earthquake damage. It was charged with providing the Chairman of the ICC "... with an assessment of its (the plan's) adequacy in respect to such topics as general direction, comprehensiveness, gaps or overlaps, and responsiveness to the objectives of the NEHRP, as established by law."

During Fiscal Year 1984, the NEHRP Policy Coordinating Group and, subsequently, the Office of Management and Budget (OMB) reviewed the recommendations of the independent advisory panel (submitted in Fiscal Year 1983) and established guidelines for revision of the plan by the principal agencies to conform with the President's budget. The independent panel had provided both a high and low budget scale for the proposed activities in the plan, and the reworking of the plan according to the guidelines provided as part of the Policy Coordinating Group and OMB reviews resulted in a level of activity between the two.

Legislation has been submitted which would change the requirement to submit an annual update to the five-year program plan required by section 5(b)(2)(E) to a requirement for submission of the plan when needed, but in any event at least every five years. Also, the section would be revised to eliminate obsolete dates, and required details to be included in the plan. The reason for this change is two fold; (1) the process of preparing the plan was time and staff intensive and we anticipate that an annual update would require commensurate resources, and (2) programmatic activities in this area are usually undertaken on a multiyear cycle; therefore an annual update would be ineffective. FEMA, through submission to Congress of the annual report, will continue to report regularly on progress being made by the agencies to accomplish the objectives in the Five-Year Plan.

The plan outlines the programs of the principal agencies in carrying out their responsibilities for the five basic elements of the NEHRP. The time period covered by the plan includes Fiscal Years 1985 through 1989.

The plan translates the purpose and objectives of the Earthquake Hazards Reduction Act into a program consisting of five major elements, and outlines specific goals and objectives for each element. The elements, along with brief descriptions of the activities they encompass, are as follows:

1. Hazard Delineation and Assessment
2. Earthquake Prediction Research
3. Seismic Design and Engineering Research
4. Preparedness Planning and Hazard Awareness
5. Fundamental Seismological Studies

1. Hazard Delineation and Assessment

Information about the earthquake risk is the foundation upon which safety measures rest: land use planning; design and construction; disaster preparedness, response and recovery; public information and education activities; and responses to predictions. Major activities under this element involve (1) determining the tectonic framework and earthquake potential of various zones in the United States, and (2) delineating, evaluating and documenting earthquake hazards and risks in urban and other critical areas of the United States. Projects conducted under this element include: regional monitoring and earthquake potential studies, national and regional earthquake hazards assessment, and post-disaster mitigation studies.

2. Earthquake Prediction Research

Accurate earthquake prediction can provide a foundation for preparedness actions that may reduce human suffering and social disruption, while posing intriguing and fundamental scientific questions. One of the most challenging problems facing the physical science community is to develop reliable methods for the timely prediction of damaging earthquakes. Activities conducted under this element include the following: obtaining and analyzing data on precursory phenomena, performing prediction experiments, performing theoretical, laboratory and fault zone studies to understand the physical processes involved in the occurrence of earthquakes, and developing a better understanding of induced seismicity.

3. Seismic Design and Engineering Research

Significant advances in understanding the response of structures to earthquake motions are being incorporated into the design of tall buildings, dams, nuclear power plants, liquified natural gas facilities, and more. However, today's knowledge is far from complete. Activities under this element are directed towards improvements in: model codes and regulations and manuals of practice for improved seismic design; efforts to educate engineers, public officials, architects, and construction personnel about improved practices; research to understand the response of structures to earthquakes and develop better information on actual and estimated ground motion; and continued progress within the Federal Government to apply proper practices to its own building projects.

4. Preparedness Planning and Hazard Awareness

Improvements in seismic design and construction primarily affect new construction. However, damages in heavily populated and industrialized areas can cause tens of thousands of casualties and damages in the billions of dollars. Therefore, it is critical to mitigate the impacts of earthquakes and prepare for an effective response. Activities within this element are directed toward improving the capabilities of all elements of the

public and private sectors to mitigate the consequences of and respond to an earthquake disaster (or the prediction of an earthquake), and developing knowledge about the decision-making and economic impacts of mitigation and preparedness. Specific projects include the development of a management strategy for coordinating earthquake hazards reduction activities, development and testing of a Federal Response Plan and strengthening of State and local preparedness planning, consolidation of earthquake preparedness planning with that for other hazards to increase the efficiency of all, development and implementation of an earthquake education and information transfer plan, and examination of the societal factors associated with the adoption and application of technological and social adjustments to earthquake hazards.

5. Fundamental Seismological Studies

Basic research is required to understand the physical processes that eventually cause earthquakes. The disciplines and technologies involved are numerous, including seismology, geodesy, satellites, lasers, and computer modeling. The activities of this element are directed toward better understanding of plate tectonics and the earthquake process; installation, operation and maintenance of an improved global and national network or seismograph stations; collection and analysis of information on the occurrence and effect of earthquakes; and support of basic and applied research to ensure that data collection and analytical techniques keep pace with advances in instrumentation and theoretical seismology.

FEMA's EARTHQUAKE PROGRAM ACTIVITIES

As in all matters related to public health, safety, and welfare, State and local governments bear the primary responsibility for the protection of life and property in the event of a serious or catastrophic earthquake. The functions of emergency preparedness planning, warning, response, recovery, and mitigation must be carried out at these levels of government, with the assistance, cooperation, and support of the Federal Government. To assist State and local governments to enhance their overall emergency management capabilities, FEMA developed the Integrated Emergency Management System (IEMS). IEMS is designed to enable State and local governments to utilize available funds and resources with optimum effectiveness and efficiency. It does so by stressing an integrated, functional approach to the management of emergencies across a full spectrum, including natural disasters such as tornadoes, hurricanes, floods and earthquakes; technological disasters such as explosions, release of hazardous materials, accidents involving radiological materials, nuclear power plant accidents, resource shortages; and possible attack.

IEMS stresses the preparedness elements common to emergencies across the full spectrum while at the same time recognizing elements unique to specific types of emergencies. Guidance for the implementation of the IEMS approach was developed in 1983,

field tested in 1984, and is undergoing full field implementation in 1985. The IEMS functional approach to comprehensive emergency management was funded last year by approximately $100 million of civil defense funds in direct program and training support to State and local governments.

The Earthquake Hazards Reduction Act, while obviously hazard specific, recognized in its original language the benefits that could accrue to overall emergency preparedness from the planning and preparedness activities related to a single hazard. Section 2(7) states:

> The implementation of earthquake hazards reduction measures would, as an added benefit, also reduce the risk of loss, destruction, and disruption from other natural hazards and manmade hazards, including hurricanes, tornadoes, accidents, explosions, landslides, building and structural cave-ins, and fires.

Under the five major elements of the NEHRP, described earlier in this statement, there is a set of program activities and tasks which are the specific responsibility of FEMA to carry out. Consistent with the language from the Act quoted above, it is FEMA's policy and intent to implement these activities within the context of IEMS to the extent possible. These activities constitute a FEMA earthquake program of five elements, in addition to the lead agency functions already discussed. The five elements of the FEMA earthquake program are the following:

I. Seismic Design and Construction Standards
II. State and Local Hazards Reduction Programs
III. Federal Response Planning
IV. Mitigation and Multihazard Preparedness Planning
V. Earthquake Education and Information Transfer

Each of these elements will be discussed in turn, both in terms of past accomplishments and planned activities for the future.

I. SEISMIC DESIGN AND CONSTRUCTION STANDARDS

The partial or total collapse of structures resulting from an earthquake is the main cause of earthquake injuries and deaths. However, casualties can occur not only from the buildings themselves but from the secondary effects of failed lifelines, such as fires caused by ruptured natural gas lines. In order to lessen these threats to human life, FEMA supports activities which can enhance the seismic safety of new and existing buildings as well as lifelines. These activities will result in design standards, practices, recommended provisions, and manuals for the different users in the construction industry.

This segment of the FEMA earthquake program is being conducted in two parallel, coordinated, and complementary groups of activities. One group is for the use of the private sector, primarily the design professions, the building regulatory

entities, and the model code and specification writers. For these users, the FEMA-sponsored end products are intended to be source documents only. The second group of activities is directed at Federal agencies, with the two-fold objective of establishing a minimum uniform seismic safety level for Federal construction and setting an earthquake mitigation example on the part of the Federal Government. In both cases, the output of this element of the earthquake program represents the most effective long-range mitigation strategy.

Federal Buildings (New)

The seismic safety requirements for buildings constructed or used by Federal agencies, as well as buildings constructed under various Federal grant, lease, and regulatory programs should be consistent, with different standards, where needed, set to satisfy the special needs of certain mission agencies. To satisfy this objective, the Interagency Committee on Seismic Safety in Construction (ICSSC), representing all Federal construction agencies, was created in 1979 and is chaired by the NBS with funding support from FEMA. By January 1981, the ICSSC had formulated and issued a draft seismic standard for new Federal buildings. In issuing the document, FEMA urged Federal agencies to use these provisions in their normal mission-oriented construction activities. The ICSSC has made a recommendation to FEMA on the most suitable process and procedures to ensure a wide acceptance and application of the standard. FEMA is in the process of assessing the policy implications of such a recommendation, which would involve a degree of mandation for Federal agencies. In the meantime, the 1981 standard is being updated and balloted by the Federal agencies.

Non-Federal Buildings (New)

In parallel with these Federal activities are the activities of the Building Seismic Safety Council (BSSC), an independent, consensus, voluntary body established under the auspices of the National Institute of Building Sciences. The BSSC enhances public safety by providing a national forum to foster improved seismic safety provisions for use by the building community in planning, designing, constructing, regulating and using buildings.

Since its establishment just 6 years ago, BSSC, with funding from FEMA, has undertaken a multiyear, multiphased, multiobjective project to: (a) assess the viability and technical validity of (including relevance, clarity, completeness, and practicability), and to refine as necessary, the Applied Technology Council's (ATC) Tentative Provisions for the Development of Seismic Regulations for Buildings into a new document; (b) identify societal and regulatory impacts of their implementation; (c) conduct a long-range program to encourage the adaptation of the resource document to local needs by the design professions, the code- and standard-writing organizations, and State and local

regulatory bodies; and (d) begin the first of the required periodic updates of this resource document.

The first objective was achieved on schedule with the completion of the trial design of the ATC provisions and the publication of the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings. The trial design process involved almost 50 buildings of different size, shape, occupancy, and construction type in nine cities, six of which are east of the Rockies. The nine cities are Memphis, St. Louis, Charleston, New York, Chicago, Fort Worth, Phoenix, Los Angeles, and Seattle. The results of the process were subjected to a consensus review and then incorporated into the NEHRP Recommended Provisions. These in turn were submitted for balloting by the 57 BSSC member organizations. The technical and philosophical topics raised by balloting are being addressed systematically and a planned second balloting is now scheduled for the fall of 1985 - a few months later than orginally planned. This delay will permit a more deliberate pace in the second balloting and in resolution of issues than was allowed during the first balloting, and foster a consequent strengthening of the consensus process.

Preparation of the manuals on societal implications and on regulatory impacts of the NEHRP Recommended Provisions is proceeding as planned, with the former expected to be ready by May 1985.

During the next phase of the BSSC contract (now being negotiated), a long-range plan will be prepared for encouraging as widespread as possible adaptation or adoption of the provisions by interested users. Complementary documents are also expected to be ready for dissemination by the end of January 1986. In the meantime, NBS is preparing the technical basis for upgrading the provisions, an effort that BSSC is expected to start in the fall of 1985 and pursue in Fiscal Year 1986. This effort will follow a consensus process identical to that used in the development of the first version of the NEHRP Recommended Provisions.

Existing Structures (Federal and Non-Federal)

The activity described so far has been directed at new construction practices; however, attention to existing construction is imperative. Spurred by tax credit incentives, the rehabilitation of structures - historical and nonhistorical, residential, and commercial - is proceeding at a rapid pace throughout the country. Most rehabilitation work is done without a set of generally accepted and applied seismic building standards and practices. This means that in areas of high and moderate seismic risk throughout the country, hazardous buildings are being given additional years of occupancy, thus exacerbating an already serious condition.

Yet, there is a considerable body of engineering and architectural knowledge on how to repair and retrofit structures to improve their seismic resistance. Additionally, practical experience resulting from the gradual application of seismic provisions to existing buildings by a few municipalities (e.g., the City of Los Angeles) is being accumulated. There is,therefore, a sufficient base of knowledge upon which to proceed with a comprehensive, multiyear effort to abate the seismic hazards created by old buildings.

For this reason, late last summer FEMA contracted with the newly-formed ABE (Applied Technology Council, Building Seismic Safety Council, and the Earthquake Engineering Research Institute) Joint Venture for the development of a comprehensive and detailed plan for this hazard abatement program. The objective of this plan is to provide FEMA, other Federal agencies, and the private sector with detailed guidelines, a suggested implementation process and identification of the resources required to carry it out. Nine papers have been commissioned and will be the foci of a workshop to be held in Phoenix this month (March 1985) to develop a broad consensus on the plan. The plan itself, based on the commissioned papers and the results of the workshop, is expected to be ready by the end of Fiscal Year 1985. Fiscal Year 1986 funds will be used to start the most urgent and high priority items identified in this plan.

Lifelines (New and Existing)

During this spring (1985), FEMA plans to contract with a broadly-based group similar to BSSC and the ABE Joint Venture to formulate a long-range plan on how to enhance the seismic safety of new and existing lifelines. As in the case of existing buildings, a great deal of activity is taking place, but a coherent, comprehensive plan of action is missing. Its preparation will be even more difficult than that dealing with existing buildings, because of the technical problems involved, the heterogeneity of the different types of lifelines, and the close intertwining of public and private sector roles and activities. The plan is not expected to be ready before the end of Fiscal Year 1986, with implementation, therefore, extending into the out years.

II. STATE AND LOCAL HAZARDS REDUCTION PROGRAM

One of the objectives of the Earthquake Hazards Reduction Act is the following:

> the development, in areas of seismic risk, of improved understanding of, and capability with respect to, earthquake-related issues, including methods of controlling the risks from earthquakes, planning to prevent such risks, disseminating warnings of earthquakes, organizing emergency services, and planning for reconstruction and redevelopment after an earthquake.

To achieve this objective, FEMA is supporting a range of earthquake specific activities in high-to-moderate-hazard States and localities identified by the USGS and FEMA. These activities typically follow a logical sequence of tasks that begins with an assessment of past and potential seismic activity in the area. Based on these assessments, vulnerability or loss studies are made to estimate primary and secondary earthquake effects, the number of possible casualties, and potential damage to critical and/or special facilities and lifelines needed for immediate response operations. Using data from these analyses, FEMA assists the State and local governments to undertake preparedness, response, recovery and mitigation planning and to integrate this planning into their overall emergency management programs. Throughout this process, the State and local governments are encouraged to implement public awareness and education programs.

Regarding the vulnerability or loss studies referred to above, the early loss-estimation methodologies were developed for California, where most NEHRP activity was then occurring. With the program's expansion to the rest of the United States, where the nature of the seismic hazards as well as building construction techniques differ from California, it became important that modified loss-estimation methods be developed and better standardized. Therefore, FEMA plans to develop a more standardized earthquake loss-estimation methodology for use throughout the entire Nation. This methodology will provide a procedure for estimating loss of life, injuries, property damage, and other socioeconomic losses resulting from earthquakes.

FEMA has made significant progress in translating the sequence of activities described above into the tasks and activities that comprise a balanced State or local earthquake hazards reduction program. In 1985, for the first time, Earthquake Preparedness Program Guidelines were included in the Comprehensive Cooperative Agreement (CCA) Guidance Package. (The CCA is the financial/administrative instrument used by FEMA to deliver comprehensive emergency management assistance to State and local governments). Currently, we are completing work on a formal Civil Preparedness Guide (CPG) for the implementation of earthquake hazards reduction programs by State and local governments. It is expected to be available for use in the preparation and planning of Fiscal Year 1986 projects. The CPG will provide information on the overall structure and content for earthquake hazard reduction measures at the State and local levels and general information on objectives, funding, government roles and integration with other emergency management efforts. While the CPG is intended primarily for the use of State and local governments, it will contain material that should be of considerable value to FEMA regional staff in their roles of reviewing and approving project applications and monitoring and evaluating the ongoing projects.

Twelve areas of high population/high earthquake risk have been identified by FEMA and the USGS; and in Fiscal Year 1985, for the

first time, FEMA is supporting earthquake hazards reduction projects in all of them. The twelve areas are Anchorage, Alaska; Puget Sound, Washington; southern California (Los Angeles and San Diego); northern California (San Francisco Bay Area); Honolulu, Hawaii; Salt Lake City, Utah; Central U.S.; Charleston, South Carolina; Boston, Massachusetts; New York State; Puerto Rico; and the Virgin Islands. These areas are all at various stages of progress in implementing their earthquake hazards reduction programs. Some are at the relatively early stage of vulnerability assessment, such as New York State; while others are involved in preparedness and response planning, such as southern California and Salt Lake City. Mitigation activities are being conducted in California, Puget Sound, and other areas; and Federal response activities, including preparation for exercises this spring, are underway in the Anchorage and Los Angeles areas.

A brief description of the activities in each of the twelve areas follows:

1. Anchorage, Alaska

Alaska has received Federal funding for earthquake planning since the mid-1970's. Completed activities include a loss study for the greater Anchorage area; an earthquake plan for the State and the City of Anchorage; an emergency communications plan for the State; and tsunami safety and flood zone maps. The State also initiated activities to upgrade its emergency power and communication capabilities, and completed a study of the time needed for the restoration of power, gas, and water utilities. Fiscal Year 1984 activities included efforts to evaluate capability shortfalls, conduct a Federal capability analysis, and initiate a Federal preparedness project. Fiscal Year 1985 activities will complete the Federal response preparedness effort.

2. Puget Sound, Washington

Previous work includes a risk assessment and vulnerability analysis completed in 1975, and a preliminary Federal response plan completed in 1981. With Fiscal Year 1981 and Fiscal Year 1982 funds, the State of Washington updated its Natural Disaster Plan, incorporating standard operating procedures for earthquake response by State agencies. In support of this effort, a disaster assistance guidebook for local governments was revised to include earthquake response activities. In Fiscal Year 1983, the State initiated a 5-year effort focusing on local preparedness, response, mitigation, and recovery activities. In Fiscal Year 1984, the objective was to create a disaster medical response capability in the Puget Sound region. Current and future work is projected to continue institutionalizing this capability and integrate it with local emergency management organizations. Also, the development of a set of mitigation strategies for land use and building design is planned.

3. Southern California

A. SCEPP. The Southern California Earthquake Preparedness Project (SCEPP), a cooperative project between FEMA and the State of California, has made the transition over the last year from being a developmental project designed to produce prototypical earthquake preparedness planning tools to the operational, implementation phase. SCEPP is now taking the materials it has developed, and its experience gained in that process, and using both to actively promote earthquake hazard awareness and preparedness throughout its five-county jurisdiction. It should be noted that, in recognition of the shift to an operational/ implementation mode, SCEPP has been transferred from the organizational authority of the California Seismic Safety Commission to that of the Office of Emergency Services (OES). This shift also facilitates the integration of SCEPP's earthquake hazard reduction activities with OES's comprehensive emergency management approach.

B. U.S./Mexico Earthquake Preparedness Project. In December 1983, the Mexico-United States Geological Phenomena Subcommittee of the Mexico-United States Consultative Committee on Natural Disasters proposed a project focussing on earthquake hazard reduction in the San Diego-Tijuana area. A workplan was prepared during Fiscal Year 1984 and work on the project is beginning in earnest this year. The seven major tasks of the project are evaluation of seismic hazard, vulnerability analysis and damage forecasting, emergency response and recovery planning, hazard reduction and mitigation, seismographic networks and information exchange, bilateral coordination, and public information and education. The workplan describes the conduct of these activities for a five-year period (Fiscal Years 1985 - 1989), and currently anticipates completion in Fiscal Year 1989. Implementation is dependent upon the budget appropriations of each nation.

4. Northern California

Fiscal Year 1984 saw the creation of the San Francisco Bay Area Regional Earthquake Preparedness Project (BAREPP), which will implement the workplan developed through the efforts of the previous Bay Area Earthquake Study (BAES) to survey and define current earthquake hazard planning and preparedness needs and priorities. Particular emphasis is being placed on developing and implementing preparedness projects and identifying mitigation opportunities for critical facilities, high-rise structures, and lifelines. This program will benefit from SCEPP's experience and materials and is expected to include similar participation from the public and private sectors.

5. Honolulu, Hawaii

Hawaii has received Federal support for earthquake studies and planning since Fiscal Year 1979, when it received funds to

complete a study of earthquake losses in the Honolulu area. With additional funding in Fiscal Year 1981, the State conducted vulnerability studies of critical facilities, lifelines, and other major hazards. Fiscal Year 1982 funds were used to develop planning guidance and begin development of a State earthquake response plan. This plan was completed in Fiscal Year 1984. Current work in Hawaii involves conducting workshops to increase awareness of the plan, preparation for an exercise of the plan, implementation of a public awareness program, and development of statewide mitigation strategies, including seismic building provisions.

6. Salt Lake City, Utah

Early efforts included the preparation of a loss study in 1976, and a Federal response plan in 1978. With Fiscal Year 1981 funds, the State prepared guidance for the development of local response plans for the counties of Salt Lake, Weber, Davis, and Utah. Fiscal Year 1982 funding was provided to Utah to initiate development of operational plans for earthquake preparedness and response in these counties. Subsequent funding was directed toward development of a five-year earthquake preparedness program for the State and completion of the four-county earthquake response plan. Current work is focusing on the detailed integration of the State response plan with those of each of the involved counties, and with all other relevant State agencies. Mutual aid agreements and table-top exercises will be other priorities.

7. Central United States

The central U.S. planning area, defined as the area which would experience damaging intensities from seismic events equal to the New Madrid event of 1811-12, encompasses all or part of 21 States. Severe damages would be expected in seven of those States. These States (Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee) formed the Central U.S. Earthquake Consortium (CUSEC) in November 1983. CUSEC was funded by FEMA in Fiscal Year 1984 primarily to coordinate the inter-state needs of these States in earthquake hazard reduction. CUSEC's first goal was to integrate each State's independently formulated multiyear earthquake workplan (funded in Fiscal Year 1983) into a comprehensive and coordinated plan for the seven-State area. Current work includes initiation of vulnerability studies for lifelines and critical facilities, identification of medical and mass care needs and delivery mechanisms, and development of a strategy for public awareness.

8. Charleston, South Carolina

The South Carolina "Seismic Safety Consortium" was formed by local initiative late in Fiscal Year 1982. A workshop was held by the Consortium in May 1982 and a white paper on the seismic threat to the southeastern United States with emphasis on South

Carolina was issued. Fiscal Year 1982 funds were provided to complete a task analysis, a needs assessment, and an inventory of existing data required prior to the conduct of the first phase of a vulnerability analysis. The inventory will be completed in Fiscal Year 1985. Preparedness planning will begin in Fiscal Year 1986 and be completed in Fiscal Year 1987. Mitigation planning will be conducted in Fiscal Years 1988 through 1990.

9. Boston, Massachusetts

The eastern Massachusetts risk assessment, completed in Fiscal Year 1984, has provided isoseismal maps detailing high-intensity areas. With the aid of the USGS, a methodology is being developed to assess damage to structures. The establishment of a seismic safety panel for the New England Region is also in the initial stages.

10. New York State

In Fiscal Year 1985 FEMA is funding a planning council to define the specific activities for this area. The council, which consists of representatives across the full societal spectrum, will have its planning affected by such factors as the availability of geotechnical information and the degree of support State and local governmental decisionmakers and others will provide. Vulnerability assessments are also planned to commence in Fiscal Year 1985, preparedness planning in Fiscal Year 1987, and mitigation planning in Fiscal Year 1989.

11. Puerto Rico

In Fiscal Year 1984, Puerto Rico initiated an earthquake vulnerability analysis by examining seismic hazard models from the National Geophysical Data Center in order to select a design event. The analysis is being conducted at the Center for Engineering and Environmental Research (CEER) at the University of Mayaguez. In April 1984, Puerto Rico presented preliminary findings at a FEMA/USGS workshop funded by FEMA. The study is expected to be completed this year. Preparedness planning is scheduled for Fiscal Years 1986 - 1988, and mitigation planning for Fiscal Years 1989 - 1990.

12. Virgin Islands

In Fiscal Year 1983 the Virgin Islands Office of Disaster Preparedness initiated an earthquake hazards planning program. In Fiscal Year 1984, a planning council selected a design event and identified critical facilities on St. Thomas, St. Croix, and St. John. In April 1984, information on the status of the assessment was presented at a FEMA/USGS workshop for which FEMA provided funding support. The vulnerability assessment is expected to be complete this Fiscal Year, with preparedness planning to take place in Fiscal Years 1986 - 1988, and mitigation planning to be conducted in Fiscal Years 1989 - 1990.

III. FEDERAL RESPONSE PLANNING

State and local resources will be inadequate to respond to the effects of a catastrophic earthquake. To save lives and provide for basic human needs, response from the Federal Government, both from the local geographic area and the entire Nation, will be required. Consequently, in recognition of the increasing threat of a catastrophic earthquake in California as well as the possibility of catastrophic earthquakes in other areas of seismic risk throughout the Nation, FEMA initiated in Fiscal Year 1982 a response planning effort that involves the entire Federal Government.

As a mechanism on which to build a base for Federal response to a catastrophic earthquake, the Subcommittee on Federal Earthquake Response Planning was established under the auspices of the Interagency Coordinating Committee. The Subcommittee, formed in August 1982, is chaired by FEMA and now involves 24 Federal and private agencies with identified capabilities and resources to contribute to a disaster response effort.

In Fiscal Year 1984, a third draft of the National Plan for Federal Response to a Catastrophic Earthquake was issued. The plan provides a national-level organizational structure to support Federal regional assistance to State and local governments. In addition to the basic plan, which focuses on policies and assignment of responsibilities, the plan includes 13 annexes which describe emergency support functions required for immediate action to protect lives and property. Including responsibilities assigned to many agencies previously not actively involved in disaster response or assistance, the focus of the plan is on support immediately after a disaster occurs - a period during which the Federal Government usually has only a limited role. The plan creates a framework for Federal response, under the provisions of the Disaster Relief Act of 1974 (Public Law 93-288), that is adaptable to any catastrophic event where Federal resources are needed at once to save and protect lives. Though still in draft form, the plan serves as an interim operating guide for Federal agencies to use should a catastrophic earthquake (or other hazard) strike before follow-on regional planning is completed.

The third draft of the National Plan was the focus of a FEMA sponsored two day tabletop exercise named RESPONSE 84, which was based on a simulated catastrophic earthquake on the southern San Andreas Fault. The lessons learned from RESPONSE 84 have now been incorporated into the fourth draft of the National Plan. This revised plan will be tested in exercise RESPONSE 85, scheduled for June 18-20, 1985, in conjunction with the FEMA Region IX (San Francisco) Earthquake Response and Assistance Plan. In this coordinated effort, Federal agency representatives will have the opportunity for the first time to address issues and support that State and local governments would require immediately after an earthquake.

Future work will initiate development of Federal regional plans to support the national Federal response to catastrophic events, and include exercises to maintain and update the National Plan and internal agency procedures.

IV. MITIGATION AND MULTIHAZARD PREPAREDNESS PLANNING

Until now earthquake preparedness planning has been conducted with an exclusive concentration on reducing seismic risk. However, seismically hazardous areas are also prone to other disasters as well. Earthquakes also trigger multiple and simultaneous disasters, such as fires, floods from ruptured dams, landslides, and toxic spills. For areas where earthquake recurrence periods are long and current seismicity is low, earthquake preparedness measures may be politically and economically feasible only if combined with those to reduce other hazards.

FEMA is attempting to develop and implement a scientifically sound methodology for comparing and ranking hazards within a geographical area and across some uniform geographical area such as a county. The effort consists of two initial tasks. The first is a literature search to identify the most accurate, useful, and current sources of information on hazard characteristics such as frequency of occurrence and magnitude of consequences. The second task is to determine the feasibility of developing a methodology for cross-hazard analysis and risk assessment using the various hazard characteristics available in existing data bases.

If a cost-effective methodology appears feasible, work would likely proceed on refining the methodology, collecting necessary information, and incorporating the methodology into FEMA's current Hazard Identification, Capability Assessment, and Multi-Year Development Plan process.

Utah Multihazard Project

Another objective of FEMA's is to develop and implement multihazard preparedness planning activities by initiating and supporting prototypical tasks in selected geographic areas. This is a key part of the total program, and its goals and tasks must use similar terminologies and procedures common to earthquake hazard reduction, such as land use, construction standards, preparedness, response, and recovery.

A multihazard approach to planning is underway in the Ogden, Utah area to assess the combined risks from seismic hazards, dam failure, and floods. This prototype activity is expected to provide cost-effective and manageable preparedness strategies and recommendations for short-term mitigation of existing hazards and for long-term land-use planning to avoid them.

Based on these results and other considerations, such as the

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availability of funds and the strength of local participation, other multihazard planning projects will be conducted. All of these new tasks are expected to be transferable, with appropriate modification, to other high-risk areas. They will focus on urgent problems such as the siting of critical facilities in hazardous geologic and hydrologic zones, and the storage of hazardous materials in structures or disposal sites in flood-prone areas, or in regions of geologic instability.

Banking and Insurance Industries - Mitigation Roles and Seismic Protection.

Because of the critical functions that financial institutions perform in an industrialized society, they need to be examined from two points of view: (1) as agents for bringing about abatement of seismic risks through their loan and related activities; and (2) as institutions, the continuing functioning of which is vital to restoration of community life after a damaging earthquake. FEMA is undertaking a two-pronged effort to examine both aspects of these two industries.

Some preliminary work was done in examining the role of banking and insurance as agents of seismic mitigation when FEMA was first formed in 1979. It has very recently been reviewed and judged to form an adequate basis for further examination. The objective is to reach policy-oriented conclusions as to what feasible mitigation roles can be performed by these two industries and what role, if any, can the public sector perform both at the State and Federal levels. In these investigations, legal and regulatory constraints are undoubtedly significant, so FEMA is at present seeking the advice and analysis of legal experts. The goal is to reach policy conclusions by the end of Fiscal Year 1986.

A private consortium is already planning to examine one aspect of the seismic vulnerability of the banking and insurance industries, namely that of data processing facilities, equipment, and personnel. FEMA is considering the feasibility of expanding this analysis to include other significant operational aspects, if any; and joining this private-sector initiative in its analytical and technology transfer activities. A joint role with NSF is under consideration for this expanded examination. Results are expected toward the end of Fiscal Year 1986.

V. EARTHQUAKE EDUCATION AND INFORMATION TRANSFER

The Earthquake Hazards Reduction Act calls for "improved mechanisms ... to translate existing information and research findings into reasonable and usable specifications, criteria and practices so that individuals, organizations, and governmental units may make informed decisions and take appropriate actions." In response to this need, FEMA is conducting an active program of earthquake education and

information transfer. At the end of Fiscal Year 1984, FEMA completed the development of a multiyear earthquake education management plan. It has had substantial input from Federal, State, and local governments, volunteer agencies, civic organizations, educators, and researchers. The plan reflects the contributions of SCEPP and other earthquake projects, FEMA's prototype community outreach projects and pilot courses, and short- and long-term marketing and media campaign strategies. Finally, this plan clearly identifies milestones and expected accomplishments to facilitate analysis, evaluation, and identification of future funding priorities.

Community Outreach

This effort facilitates outreach programs through existing State and local public and private safety offices; the American Red Cross (ARC); schools, colleges and universities; community-based organizations; and youth and religious groups to enhance dissemination and use of earthquake education materials.

In August 1983, FEMA awarded funds to support, through Fiscal Year 1986, two pilot Earthquake Education Centers (EECs) - one at the Baptist College in Charleston, South Carolina, and the other at the Tennessee Earthquake Information Center in Memphis, Tennessee. These institutions, which have been monitoring seismic networks, are viewed by the scientific community, State and local emergency managers, the media, and the public as authoritative providers of earthquake information.

EEC activities focus on developing and testing a variety of ways to increase community access to information on earthquake risk and to improve individual and community capability to carry out life-protecting actions during and following an earthquake. Planning approaches include establishing an advisory board composed of community representatives and Region, State, and local emergency services officials; recruiting and training a cadre of community outreach volunteers; and modifying existing products to address regional seismic risk and to reflect users' language/style and levels of understanding.

In September 1983, FEMA awarded funds to the University of Washington, through the State of Washington, to develop a comprehensive earthquake safety and education program for schools in Seattle. This 3-year pilot project is designed to reduce the vulnerability of the school population to the life-threatening consequences of future earthquakes and to improve students' knowledge and understanding of earthquake causes, effects, hazards, and preparedness measures.

FEMA is also developing strategies to provide earthquake information along with information on other hazards in support

of multihazard education programs. To this end, FEMA initiated a series of competitive challenge grants to stimulate local public information demonstration projects; provided a grant to the Children's Television Workshop, producer of TV's Sesame Street, to develop a multihazard program for youth; and initiated a series of emergency information exchanges. This latter activity will bring together ARC, State and local emergency personnel, private industry, and trade groups to stimulate cooperative multihazard awareness efforts and increase capability to deal with citizen information needs.

Information Transfer

This effort is intended to enhance the transfer of hazard reduction information to specific users through workshops and special courses. With USGS, FEMA sponsors workshops designed to increase the hazard awareness of elected officials and influential public and private policymakers in high-risk areas. Since 1981, workshops have been held in Puerto Rico; the Virgin Islands; New York State; Boston, Massachusetts; Knoxville, Tennessee; St. Louis, Missouri; Little Rock, Arkansas; Charleston, South Carolina; and Salt Lake City, Utah. Future workshops are being planned for Puerto Rico, Anchorage, and Los Angeles.

FEMA also sponsors additional conferences to facilitate information transfer. On November 1-3, 1983, the Washington State Department of Emergency Services and the Western States Seismic Policy Council (WSSPC) hosted a National Seismic Policy Conference in Seattle. This conference, supported wholly by a grant from FEMA, was designed to bring together representatives from the States and Territories (about 44) that are subject to high to moderate seismic risk to discuss common problems, exchange information, and promote the adoption of earthquake risk reduction programs throughout the Nation. It represented the first major attempt to disseminate knowledge. techniques, and lessons learned to all States and to transfer project materials from ongoing State projects. As such, the conference paved the way for future strategy planning conferences.

In cooperation with the WSSPC and with funding from FEMA, the Central U.S. Earthquake Consortium conducted a National Earthquake Conference in St. Louis, Missouri, on June 2-5, 1984. The conference focused on (1) the vulnerability of lifelines to seismic events, (2) medical and mass care needs associated with a seismic event, and (3) the role of private industry in earthquake hazards reduction efforts.

Hazard Specific Courses

In Fiscal Year 1982, FEMA provided funds for the first in a series of special topic courses on hazard mitigation. This course, entitled "Earthquake Hazard Mitigation for Utility

Lifelines," is intended to provide city and county public works directors, engineers, utility company and special district officials, and others with information on how to: (1) assess the potential impact of earthquake hazards on utility systems, (2) lessen the effects of ground shaking on critical components of these systems, and (3) develop procedures to hasten system recovery following an earthquake. This course, tested in the San Francisco Bay Area in April 1983 and modified in Fiscal Year 1984, will be deployed as appropriate in the future.

Special courses will be developed in the future to address such topics as earthquake fire hazards in high-rise, high occupancy buildings and non-structural earthquake hazard mitigation for hospitals.

Southern California Earthquake Preparedness Project (SCEPP) Prototypical Materials

SCEPP was designed to produce prototypical earthquake preparedness educational and planning materials that would be transferable to other high risk areas of the United States, in addition to its goal of stimulating increased preparedness within the five county region around Los Angeles. In 1984 SCEPP delivered to FEMA the products it had developed since its creation in 1980. These products consisted of comprehensive earthquake preparedness planning guidelines for cities, counties, and corporations; and manuals, brochures, and slide-tape shows designed to provide earthquake planning and preparedness information (both technical and non-technical) to a wide range of audiences including local government elected and appointed officials, the general public, the school community (children, teachers, administrators and parents), the disabled, the Spanish-speaking, business and industry, etc. FEMA has reviewed these materials to determine how transferable they are to areas outside of southern California and to determine the most effective means of disseminating them to other areas. We are currently beginning the process of reproducing the materials in appropriate formats, and expect to have them available for distribution later this year. We expect, based upon SCEPP's own research and the comments we received during the review of the products, that the materials will be well accepted for use as models, which will then likely be adapted by various States, agencies, and organizations for their own particular use and audiences. The availability of the SCEPP materials is a major advance in the status of earthquake education and information transfer.

SUMMARY

The intent of this narrative has been to provide an overview of the range of activities that are part of the NEHRP. The programis broad in scope and involves many disciplines: geology, geophysics, seismology, architecture, engineering, law, economics, and the social and behavioral sciences, to name a

few. The purpose and goal of the Earthquake Hazards Reduction Act, the reduction of loss of life and property from future earthquakes, can be achieved only with the combined participation and cooperation of private individuals and organizations, business and industry, academia, the scientific community, neighborhood groups, and agencies of local, State and Federal government.

As the preceding narrative has described, much has been accomplished in the years since passage of the Act. Importantly, in many parts of the country, there is a much greater awareness of the hazard posed by earthquakes, as well as a better understanding that it is possible to reduce these hazards.

The progress and accomplishments achieved to date are significant and many; they should not, however, obscure the fact that there is much remaining to be done. More knowledge is needed in the fields of seismology, earthquake prediction, earthquake engineering, and societal response to hazards and disasters. Continued effort is needed to implement the results of research through codes and standards of practice in preparedness, response, recovery, and hazard mitigation, so that the suffering and losses caused by earthquakes can be reduced. FEMA looks forward to its continuing role in this effort.

Mr. WALGREN. Thank you very much, Dr. Speck.
Let's turn to Dr. Peck.

STATEMENT OF DR. DALLAS L. PECK, DIRECTOR, U.S. GEOLOGICAL SURVEY, ACCOMPANIED BY DR. JOHN R. FILSON, CHIEF, OFFICE OF EARTHQUAKES, VOLCANOES, AND ENGINEERING

Dr. PECK. Thank you, Mr. Chairman.

As Director of the U.S. Geological Survey, I am very pleased to testify before the committee today on the reauthorization of the National Earthquake Hazards Reduction Program.

I would like to supplement my prepared testimony that was submitted for the record with a few comments on the program and then would be happy to answer questions at the proper time.

One hundred years ago, nearly 100 years ago, on September 1, 1886, John Wesley Powell, the Director of the Geological Survey, sent J.W. McGee to Charleston, SC, to examine the effects of a large earthquake that had occurred nearby the previous day. Today the Geological Survey continues to maintain its commitment to the study and reduction of earthquake hazards under the aegis of the National Earthquake Hazards Reduction Program.

With proposed funding of over $34 million in fiscal year 1986, earthquake studies represents the largest single program in the budget of the Geologic Division. There are over 400 employees in the Geological Survey working on earthquake research or related activities, about half of which are scientists and engineers.

During the current fiscal year we have a total of 110 contracts with universities, State agencies, and private firms for studies that complement and extend the work done within the Survey. About a quarter of our annual appropriation is used to support these contracts.

The USGS maintains research and data analysis facilities in Menlo Park and Pasadena, CA; and Golden, CO; to carry out work related to the Earthquake Program. Our research primarily addresses problems in earthquake hazards assessment, earthquake prediction, long-term earthquake potential, and engineering seismology.

We provide 24-hour monitoring of national and worldwide seismicity and other services through the National Earthquake Information Center. We support, in some cases with other Federal agencies, the operation of regional seismic networks in several western States, the central Mississippi Valley, and the Northeastern United States. These networks are used to monitor the current seismicity of the country, to identify active geologic structures and to assess future earthquake hazards.

We maintain the National Strong Motion Network to provide data on strong earthquake shaking for engineering design purposes. For earthquake prediction research, we support laboratory and theoretical studies and extensive networks of instruments and surveys, chiefly along the San Andreas Fault in California.

In fiscal year 1984 Survey scientists published a total of over 400 reports, maps, and abstracts giving the results of the earthquake research. Since 1978 we have conducted 13 workshops with the support of other agencies, to describe the application of this research

to State and local officials, the professional private sector and the general public.

Our earthquake hazard assessments are serially focusing in 3-year intervals on earthquake-prone areas of the country. A major report on earthquake hazards in the Los Angeles region has just been completed and will be published this summer.

We are currently working closely with the State of Utah on earthquake hazards along the Washach Front, a region that contains the populous cities of Provo, Salt Lake City, and Ogden.

We have formal agreements with many foreign countries with programs in earthquake prediction and earthquake hazards mitigation research. The most active of these exchanges are with Japan and the People's Republic of China. We maintain communication with scientists in the Soviet Union working on similar problems.

We are particularly proud of the scientific accomplishments achieved through the National Earthquake Hazards Reduction Program, and I would like to point to a few of these. In the area of crustal deformation, our geologic and geodetic studies have allowed us to determine how and at what rates the Earth crust is deformed or strained in various parts of the country. Detailed geologic studies of fault zones have allowed us to determine how often a particular fault zone has broken in the past.

Far beyond the extent of the historical record, the combination of geodetic and earthquake recurrence studies has provided quantitative estimates of earthquake potential along the San Andreas Fault and elsewhere. Regional seismograph networks are being used to define the seismicity patterns in active geologic structures in earthquake-prone areas. We have demonstrated that reliable epicenters can be generated by computer processing, automatically, accurately, and within a matter of seconds.

We have completed a series of national-scale ground-shaking maps that are being incorporated into building codes. The understanding of the physics of earthquake sources, the details of how a fault breaks, have increased dramatically through theoretical and observational studies. The understanding may be used to estimate the strong ground shaking under specific conditions.

We have developed theoretical and laboratory models for earthquake prediction. These models are being used to guide well-focused earthquake prediction experiments, using instruments specifically developed and designed for prediction.

In summary, we have a vigorous program in earthquake hazards reduction studies. Working with FEMA, the National Bureau of Standards, and NSF, we are making progress toward the goals of saving lives and reducing losses from earthquakes. We look forward to continuing this work.

Thank you.

[The prepared statement of Dr. Peck follows:]

STATEMENT OF DR. DALLAS L. PECK, DIRECTOR

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

BEFORE THE

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

MARCH 19, 1985

Mr. Chairman, I am pleased to appear before this subcommittee to participate in a hearing on the reauthorization of the Earthquake Hazards Reduction Act of 1977. This is the fifth opportunity for the U.S. Geological Survey (USGS) to review its program and progress achieved through research and other activities authorized by the National Earthquake Hazards Reduction Act of 1977. The USGS has been a full and active participant in the National Earthquake Hazards Reduction Program for eight years. The USGS is primarily a scientific bureau engaged in geological and hydrological research, natural resource assessments, data collection, and mapping. Within the national earthquake program our chief responsibilities are for earthquake hazards assessments, earthquake prediction research, and earthquake data and information dissemination. Additionally, however, we have

played a key role in working with State and local governments in the utilization of earthquake hazards studies and the development of policies for earthquake hazards reduction. In this testimony we shall outline briefly the organization of our earthquake hazards program, give highlights of our activities during the past two years, and indicate future directions of our work. Further details of our past accomplishments and future plans can be found in the National Earthquake Hazards Reduction Program reports to Congress for fiscal years 1982, 1983, and 1984 and the recently completed Five-Year Plan of the program for fiscal years 1985-1989 also provided to the Congress.

Overview of the USGS Earthquake Program

The activities of the USGS under the National Earthquake Hazards Reduction Program are conducted in the Office of Earthquakes, Volcanoes, and Engineering of the Geologic Division. This office is responsible for work on all geologic hazards--earthquakes, volcanoes, and landslides--and in this respect it is probably unique in the Federal Government. The organizational structure allows for certain economies in research, monitoring, and instrument development, in that some techniques can be applied to the study of more than one geologic hazard.

The funding for the USGS earthquake program has remained fairly constant over the past eight years; in FY 1978 $30.2 million was

appropriated for earthquake studies; in FY 1985 this figure is $36.6 million and the President's budget for FY 1986 contains a request for $34.6 million, which will be adequate for us to carry forward this important work. Each year about one-quarter of our appropriation is applied to grants and contracts to support complementary investigations by universities, State agencies, and private firms.

In FY 1983, after thorough review, we reorganized our earthquake-related activities into five major elements. This reorganization reflects progress that has been made to date and redirection of our resources into those areas where we believe the greatest return can be realized. The five elements of our current program and a brief description of these elements are given below.

I. Regional tectonics and earthquake potential. The objective of this element is to understand the geology of an earthquake-prone region and estimate its earthquake potential through studies of fault slip rates, characteristic and maximum earthquakes, and earthquake recurrence intervals. Supported activities include the mapping and characterization of active faults, operation of regional seismograph networks to monitor current seismicity and to identify active and potentially hazardous geologic structures, and the combination of geological and geophysical data to yield quantitative estimates of regional earthquake potential. This information can be used not only in the focusing of our own on-going efforts, but also by other

Federal, State, and local agencies in the direction of earthquake mitigation and emergency response planning activities. In FY 1985, approximately $8.5 million will be spent on work under this element.

II. Earthquake prediction research. The objective of this element is to predict the time, place, and magnitude of damaging earthquakes. Theoretical, laboratory, and observational studies are being carried out as part of our research. Our chief observational effort is to measure various physical and chemical properties of the Earth's crust along active faults and to determine how these properties vary prior to large earthquakes. These field experiments require considerable judgement and patience because we have to assess where earthquakes are likely to occur, install the instruments, and then wait for nature to complete the experiment. The earthquake potential studies carried out under the first program element described above are of great value in choosing those areas where measurements for earthquake prediction purposes should be concentrated. In addition to field experiments, we also support theoretical studies and laboratory experiments that allow us to develop realistic physical models for rock failure and earthquake occurrence. In the current fiscal year, we are spending approximately $14 million on earthquake prediction research.

III. Regional Earthquake Hazards Assessments. This newly created element has as its objective the delineation, evaluation,

and documentation of earthquake hazards and risk in specific areas. It establishes a basis for specific loss-reduction measures at the local level. The goal is to provide the integrated, comprehensive research and generic information needed to reduce earthquake losses in populated areas through understanding of the source, size, frequency of occurrence and physical effects of earthquakes. These effects include ground shaking, fault rupture, and landslides and liquefaction caused by strong earthquake shaking. Our strategy is to build a foundation of knowledge of the earthquake hazards in all seismic regions of the United States and serially focus on each individual region during a three-year period, summarizing and synthesizing what we have learned. This element has a strong component of research application: workshops involving scientists, government officials, and the general public are held in each region to describe the problems and to explain how State and local officials and the private sector may use USGS research products to reduce earthquake hazards. In FY 1985, $5.9 million is being directed toward support of this element.

IV. Earthquake Data and Information Services. The objectives of this element are to provide timely information to the public and to public safety officials on earthquake occurrence and to collect, archive, and distribute data for seismological research. We operate the National Earthquake Information Center in Golden, Colorado, which provides 24-hour monitoring of domestic and foreign earthquake activity. With support of other

Federal agencies and in cooperation with many foreign institutions, we maintain a 130-station worldwide seismograph network. Data from this global network are used in general seismological research, not only by the USGS but also by scientists supported by the National Science Foundation, Department of Defense, and other agencies. Funding for this element this year is $4.4 million.

V. Engineering Seismology. This element is concerned with the measurement, analysis, and theoretical estimation of strong shaking of the ground and structures near earthquake epicenters. The results are used by engineers and architects in the design of earthquake-resistant structures. The data are extremely important in the siting, design, and construction of critical facilities. In FY 1983, responsibility for the National Strong Motion Network was transferred from the National Science Foundation to the USGS. This is a network of specially designed instruments that record the very strong shaking of nearby earthquakes; shaking that exceeds the recording range of conventional seismometers. This "strong motion" network consists of about 1,000 instruments; about half of these we maintain on behalf of other agencies such as the Corps of Engineers and the Veterans Administration. Under this element we support research to develop the theoretical basis for estimating the amplitude, frequency, and other characteristics of strong ground motion, and to develop new analytical techniques to provide the most useful presentation of strong motion data to the engineering com-

munity. In FY 1985 support for this element is $3.2 million.

Program Highlights

We would like now to call your attention to those aspects of our program we feel are of particular significance.

Earthquake Potential Estimates

Research supported by the USGS on quantitative, earthquake potential estimates (in a sense, long-term earthquake predictions) and estimates of strong ground shaking due to earthquakes has proceeded rapidly, providing significant new information on the long-term likelihood of major earthquakes in seismically active areas. Geologists at the USGS, the California Institute of Technology, and other institutions have, through detailed studies of fault zones, demonstrated that the dates of large prehistoric earthquakes can be determined from the geologic record. Scientists from Columbia University, the University of California, and the USGS have combined these results with seismological and other data to provide quantitative estimates of recurrence times of earthquakes in California, Nevada, and elsewhere. From estimates of recurrence times and knowledge of the last large earthquake in a region, general or long-term predictions, accurate to within a few years or decades, may be made. Figure 1 summarizes the results of this type of study for the San Andreas fault in California.

The results of this work can be used to direct further research and mitigation efforts. If, for example, limited state or local resources are available for strengthening highway bridges, earthquake potential estimates can be used to define those areas where earthquakes are more likely to occur and where strengthening should begin.

The Parkfield Earthquake Prediction Experiment

On the earthquake potential map of the San Andreas fault shown in Figure 1, that portion of the fault near Parkfield, California, shows a high probability of experiencing a magnitude 6 earthquake within the next 30 years. Although other regions of the State may experience magnitude 6 events before the next occurs near Parkfield, this 16-mile long section of the fault has a well determined earthquake history from which the magnitude and approximate time of the next earthquake can be estimated. Earthquakes have occurred near Parkfield in 1857, 1881, 1901, 1922, 1934, and 1966, with an average recurrence time of about 22 years. If the next Parkfield earthquake follows this pattern, it should occur within the next few years.

The last three Parkfield earthquakes share remarkably similar, characteristic features. These features--magnitude, length and location of rupture along the fault (rupture zone), and starting location of the fault break (epicenter)--define the

characteristic Parkfield earthquake. The concept of a characteristic earthquake with recurring features means that an experiment to predict that event a few hours or days before it happens can be tailored to these characteristic features. Since the likely time of occurrence of the next Parkfield earthquake is near, and because previous events there have been so similar, Parkfield provides a unique opportunity to conduct an experiment to observe variations in the crust of the Earth that may precede the earthquake.

We are currently putting substantial effort into monitoring the state of the Earth's crust in the Parkfield region. Seismometers, strainmeters, creepmeters (instruments that measure movement on the fault), geodimeters (very sensitive geodetic measurement devices using laser light), and other instrumentation have been installed and are being monitored. Data from this equipment are collected at a central location and quickly analyzed on a continuous basis.

The results of both the scientific studies and information transfer processes related to the Parkfield experiment will be very important to future work on earthquake prediction.

Earthquake Prediction Strategy

The Parkfield study and recent consideration and discussion of various options based on specific earthquake prediction

experiments have helped define our observational strategy for earthquake prediction.

At Parkfield, we have a well-developed concept of the earthquake we are trying to predict--its magnitude, location, and the time interval in which it is expected. The design of the Parkfield observational experiment has been made with reliability and redundancy in the instrumentation in mind to ensure that accurate and continuous data are obtained. Instruments of different design to measure the same physical phenomena are installed near each other; instruments of the same design are deployed in tandem. These efforts are being made to minimize the chances of being fooled by a spurious signal related to one instrument or one design, and to increase our chances of recognizing real precursory phenomena as they appear on several instruments.

We see our earthquake prediction efforts elsewhere being influenced by this concept--the deployment of a cluster or clusters of instruments concentrated along specific sections of the fault for the purposes of predicting earthquakes thought to be characteristic of that section. During the autumn of 1984 we developed a strategy paper on options for earthquake prediction based on this reasoning. The paper has been reviewed by several groups, including a committee of the National Research Council (NRC) and the California Seismic Safety Commission (CSSC). The paper considered strategy options ranging from continuing the present research program including the Parkfield experiment, to

adding a few additional clusters in southern California in regions where specific events are expected, to deployment of 40-60 clusters throughout California. All groups endorsed the cluster approach and our activities at Parkfield and some indicated we should proceed with a few more clusters in other regions of southern California. There was no support for options involving comprehensive deployment of 40-60 clusters throughout the State.

Research Application

We have, since 1978, conducted a series of 13 workshops to address specific earthquake problems of regional or local interest, to present the state-of-knowledge regarding these problems to State and local officials, and to lay the course for future work. These workshops, conducted by the USGS and supported by the USGS and other Federal, State, local, and private organizations, have been extremely effective mechanisms for the diffusion of knowledge about earthquake hazards throughout the Nation and about what can be done to reduce them. The workshops have brought together more than 1,000 producers and users of earthquake hazards information in almost every earthquake-prone part of the United States. In general, we have been concentrating on areas outside of California, areas in which the earthquake problem may be less well understood, and local officials and the public less well informed on the issues. The proceedings of each of these workshops have been

published in a USGS report.

The first workshop on "Communicating Earthquake Hazards Reduction Information" was held in Denver in 1978. Others have been held in Los Angeles, California; Santa Fe, New Mexico; Knoxville, Tennessee; St. Louis, Missouri; Charleston, South Carolina; and Albany, New York. Additional workshops are planned for Anchorage, Alaska; Los Angeles, California; and Cheyenne, Wyoming. These workshops have contributed to the formation of State and regional seismic safety organizations and commissions. Such organizations currently are active in California, Tennessee, Kentucky, South Carolina, New York, and the Central Mississippi Valley. Legislation is pending for a seismic safety commission in Washington State, and planning is underway for a New England seismic safety organization. Recently, the California Seismic Safety Commission authorized the drafting of a "California (Earthquake) Hazards Reduction Act" bill to describe a "state multiyear seismic safety program.".

Clearly, the research and activities supported by the National Earthquake Hazards Reduction Program are reaching the State and local level and steps are being taken to implement the results of the program.

Earthquake Studies in the Eastern United States

Evaluating seismic hazards and earthquake potential in the United

States east of the Rocky Mountains is complicated by the relative infrequency of large earthquakes and by the general absence of mappable, active faults. As a result, the association of seismicity with geologic structures showing surface expression, like those found in the Western United States is difficult. The earthquake hazards and risks from earthquakes in the Eastern United States are none-the-less real: damaging and destructive earthquakes are known to occur, the crust of the Earth transmits seismic shaking to much greater distances with less attenuation in the East compared to the West, population densities are high, and many of the population centers have significant numbers of older buildings not designed or constructed to modern building codes.

The cause--or causes--of widespread but infrequent seismicity in the Eastern United States generally is not well understood. Much has been learned in the last decade, however, and there is an accumulating body of evidence that indicates that eastern seismicity is associated with ancient (geologically speaking) fault zones that are rejuvenated by modern stress patterns in the Earth's crust. It is now thought, for example, that some earthquakes along the eastern seaboard are associated with faults that may have initially formed about 200 million years ago during the opening of the Atlantic basin. The difficulty lies in determining the cause and orientation of modern stress regimes and the geometries and conditions that cause ancient faults to be reactivated by modern stress patterns.

Since these ancient structures are almost always buried beneath younger geologic strata, defining their nature and geometry relies heavily on expensive, deep-sounding techniques originally developed for oil exploration. Perhaps the most complete investigation conducted so far in the Eastern United States has been in the New Madrid seismic zone of the central Mississippi Valley, the site of major earthquakes in 1811 and 1812. Here geologic, aeromagnetic, gravity, and seismic reflection and refraction techniques have defined a northeast-southwest trending zone of faulting in the crust beneath the Mississippi River valley in adjoining parts of Arkansas, Missouri, Kentucky, and Tennessee. This zone or rift is thought to have been formed more than 600 million years ago; however, contemporary seismicity in the region shows close association with these buried ancient faults. Present-day seismicity and crustal movements represent the response of these structures to the current east-west compressive stress field.

These studies have a significant practical application. Once the conditions for the reactivation of ancient structures are defined, and their locations determined, earthquake recurrence intervals and areas of high, and low, seismic risk in the Eastern United States can be specified with higher confidence and accuracy.

Studies similar to those in the Central United States have been carried out in the Charleston, South Carolina, region near the epicenter of a large earthquake that occurred in 1886. These studies have proceeded with cooperation and support from the Nuclear Regulatory Commission; however, the joint effort has been unsuccessful in identifying a buried structure as the cause of this earthquake. Recently, important information has come to light regarding past earthquakes in the Charleston region. Detailed geologic studies of the upper tens of feet of soil in the region show features that indicate that three or four earthquakes, including and of similar magnitude to the 1886 event, have occurred over the past twenty to thirty thousand years.

These results indicate that the 1886 Charleston earthquake was not a unique event and the yet undiscovered structure or geologic feature that gave rise to it is capable of future seismic activity.

Future Program Directions

During the next few years, our earthquake studies will concentrate more on those techniques and approaches that have enjoyed greatest success in the past.

Detailed geologic studies of fault zones have proven extremely valuable in the assessment of earthquake potential and hazards. This work involves detailed fault mapping and excavation of fault zones, primarily in the western United States, to determine the level of prehistoric earthquake activity. This work will be sustained and expanded when possible.

The seismometers in many of our dense, regional, seismograph networks were designed and built over 20 years ago, and many of our current recording practices were developed before digital technology was widespread. The costs of maintaining conventional networks and of data transmission via telephone lines have risen sharply in the past few years. These increases and the technical limitations of current systems are forcing us, in some regions, to consider other monitoring strategies. Such strategies may employ fewer instruments of modern design along with digital data processing, transmission, and analysis. These modern systems have the promise of providing new information on regional seismicity, essential to the assessment of earthquake potential.

In earthquake prediction research, as described above, we shall continue to concentrate instruments at specific sections of a fault where a characteristic earthquake has been defined and the potential is high for its recurrence. Experiments similar to the one being developed at Parkfield represent the most rational observational approach to earthquake prediction. Theoretical and laboratory studies will be continued to form a basis for development of an understanding of the observational experiments.

Regional earthquake hazards assessments are now in the second year of a three-year concentrated effort in Utah. With the cooperation of the State, through its Geological and Mineral Survey, we are making a detailed study of the earthquake hazards along the Wasatch Front, the area containing the towns of Provo, Salt Lake City, and Ogden. Our next target area for a detailed hazard assessment will be south central Alaska, the region containing Anchorage and environs. Preliminary discussions are underway with Alaska State officials to formulate and formalize this program.

We shall continue to work closely with the Federal Emergency Management Agency in activities that foster the implementation of loss-reduction measures in the various seismically active regions of the Nation.

In the area of earthquake data and information collection and dissemination we shall maintain our current services while we

work with the National Science Foundation and the Defense Advanced Research Projects Agency to improve the quality of da available from worldwide sites.

Finally, we shall work closely with the engineering commur to ensure that the data and analyses we are providing on str earthquake shaking are meeting their needs and requiremen.s. We shall continue our theoretical studies based on this information to increase our understanding of the physics of the earthquake source and thus predict strong earthquake shaking under conditions where no observations are available.

Conclusion

This concludes the testimony on the authorization of the USGS to continue work in the National Earthquake Hazards Reduction Program during Fiscal Years 1986 and 1987. In this testimony we have reviewed briefly our current program, highlights of our progress, and future directions we intend to pursue. The accomplishments of the program are significant and the level of understanding and awareness of earthquake hazards in the United States is much greater than it was when the program began in 1978. Although much work remains to be done, the efforts that have been made so far provide a solid base for extending our progress efficiently and effectively.

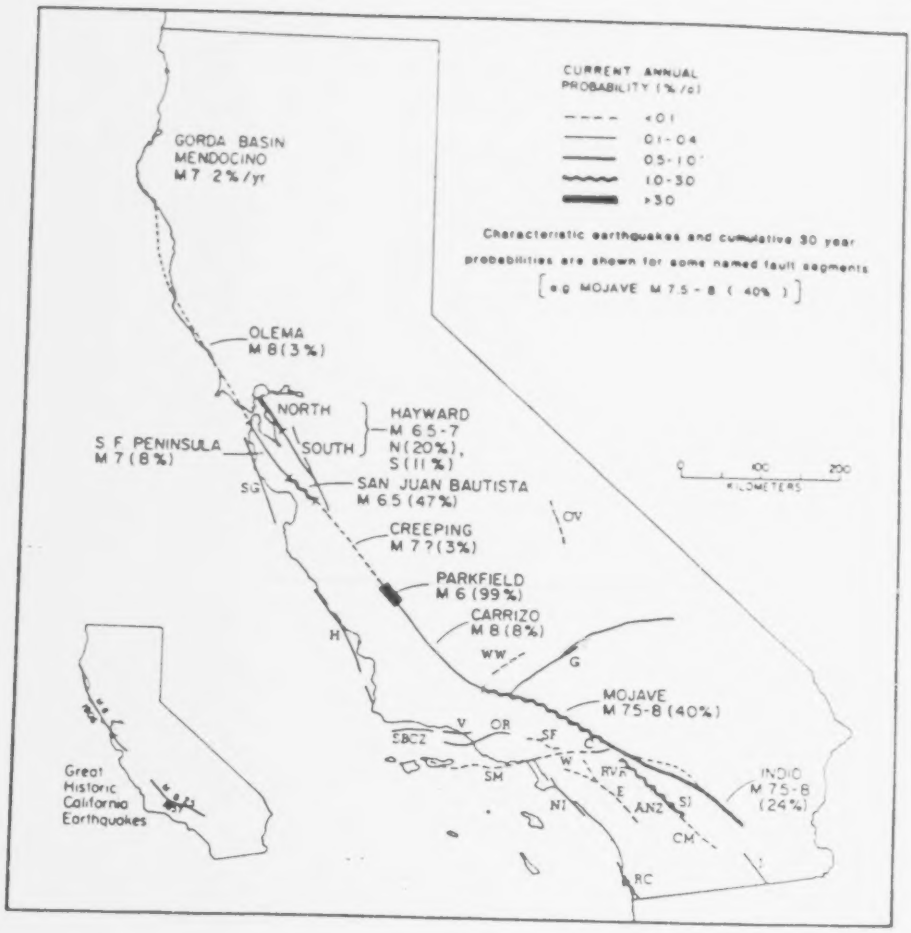
CURRENT ANNUAL PROBABILITY (%/a)
<.01
.01-.04
.05-.10
.10-.30
>.30
Characteristic earthquakes and cumulative 30 year probabilities are shown for some named fault segments
[e.g. MOJAVE M 7.5-8 (40%)]
GORDA BASIN MENDOCINO M 7 2%/yr
OLEMA M 8 (3%)
NORTH
SOUTH
HAYWARD M 6.5-7 N(20%), S(11%)
S F PENINSULA M 7 (8%)
SG
SAN JUAN BAUTISTA M 6.5 (47%)
CREEPING M 7 ?(3%)
OV
PARKFIELD M 6 (99%)
CARRIZO M 8 (8%)
H
WW
G
MOJAVE M 7.5-8 (40%)
V
OR
SF
SBCZ
C
W
RVR
SM
E
ANZ
SJ
INDIO M 7.5-8 (24%)
NI
CM
RC
0
100
200
KILOMETERS
Great Historic California Earthquakes

FIGURE 1

Mr. WALGREN. Thank you very much, Dr. Peck.
Dr. Suh.

STATEMENT OF DR. NAM P. SUH, ASSISTANT DIRECTOR, ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. SUH. Mr. Chairman and members of the subcommittee, I am pleased to be here to report to you on the status of earthquake hazard mitigation research at NSF. Since we have submitted a written testimony, I will be brief and I will just make a few comments on some relevant points.

Since the Earthquake Hazard Reduction Act of 1977, the National Science Foundation has obligated $195 million on seismic research. Approximately 68 percent of the funds have been obligated by the Engineering Directorate and 32 percent in the Astronomical, Atmospheric, Earth and Ocean Sciences Directorate.

The overall NSF Program can be divided into two subsegments. One deals with basic scientific research on the motion and structure of the Earth's crust and its relationship to the genesis of earthquakes. The second components deals with engineering research for mitigation of earthquake hazards through better understanding of siting and geotechnical issues, structural response, response of architectural and mechanical elements, and systems issues ranging from effective application of research efforts, information dissemination, technology transfer, assessment of various mitigation measures, and lifeline support systems.

The research we have supported at the National Science Foundation has resulted in many good things, and I would like just to cite some of these.

First of all, because of the act that Congress passed, the United States now has the strongest academic community in the world in the area of seismic research, both in the basic geophysics area as well as in the engineering field. The research results have been incorporated to improve the building codes, and that is a major contribution. And also, much of the research now has resulted in design aids in the form of computer software and other information which are being used by the community. We also have much better understanding of how earthquakes are generated and how they propagate.

Thanks to much of the engineering research, new design concepts such as the use of eccentric braces, new base isolation techniques have now been introduced, and these are being tested and used.

Also, we now have new legislation in State and local governments which reduces the liability of local officials, which would encourage them to implement new technological breakthroughs without being concerned about the personal liability.

Finally, we have promoted international cooperation to gather data from other countries as well as cooperate in the research projects.

I think we can go on and list many other accomplishments of our researchers in the community. However, suffice it to say that the continued support of the research community has resulted in the mitigation measures envisioned by the Congress in 1977. Notwith-

standing these advances, obviously we still have much more research to do. The question then is, where do we go from this point, and I would like to address some of the issues related to our future directions.

I would like to make about six different points about what are the things that we at least hope to pursue during the coming years. First of all, we should continue to support the research and maintain the strength we have in the research community. Through this kind of research support, we will continue to advance fundamental understanding in geophysics and earthquake engineering. Also, we will continue to develop better design methodologies that can resist earthquake ground loading on our structures and then even design better lifeline support systems.

Also, this kind of research effort should be actively promoted so that we can transfer this technology to the users and do a better job in information dissemination. At this point the National Science Foundation's Engineering Directorate is devoting about 17 percent of its budget to this earthquake engineering program, which is a substantial sum of money in a relative sense, in light of our limited resources available at this time.

We are also considering undertaking systems studies so that we can identify some of the major issues involved in mitigation of earthquake hazards so that we can bring about more effective use of our research and research results. And for this purpose we are thinking of contacting a firm outside of this community and see if we can have unbiased assessment of the major issues that underlie this field.

Another new thinking that we have on the earthquake engineering mitigation area is this matter of perhaps establishing a center that can deal with mitigation of earthquake hazards. The purpose of the center would be to promote technology transfer and then enable the undertaking of a coherent and systematic research such that we can transfer this technology more quickly to the user community. And we are thinking that we should do this jointly with the State governments. We would like to establish the center under joint funding between the Federal and State governments. We would like to pursue this and explore whether or not such a center concept is a feasible thing.

Another major item that we are considering is the possibility of undertaking some feasibility studies so that we can evaluate whether or not large-scale test facilities ought to be established in the university community. And we would like to discuss this matter with everyone concerned and establish our position on this matter during the months to come.

In conclusion, I would like to make the following three points. I think the earthquake engineers in the United States are the best in the world, and we need to make certain that this community maintains its strength through proper support provided by the Federal Government.

Second, we need to develop both broad fundamental research and more focused innovative research on problems that are most significant in fact of mitigation of earthquake hazards.

Finally, the research community has responded to the challenges posed by the Congress in the past. I believe that with adequate en-

couragement, they will continue to do their best to meet the needs of the Nation in this important area in the years to come.

Thank you.

[The prepared statement of Dr. Suh follows:]

National
Science
Foundation

STATEMENT OF

DR. NAM P. SUH

ASSISTANT DIRECTOR FOR ENGINEERING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

MARCH 19, 1985

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEES

I AM PLEASED TO REPORT TO YOU TODAY ON THE STATUS OF EARTHQUAKE HAZARD MITIGATION RESEARCH AT NSF. SINCE THE PASSAGE OF THE EARTHQUAKE HAZARDS REDUCTION ACT IN 1977, NSF HAS OBLIGATED ABOUT $195 MILLION ON SEISMIC RESEARCH IN THE DIRECTORATES FOR ENGINEERING (ENG) AND FOR ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES (AAEO). APPROXIMATELY 68% OF THE FUNDS HAVE BEEN OBLIGATED BY THE ENGINEERING DIRECTORATE AND 32% IN THE ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES DIRECTORATE.

UNDER THE EARTHQUAKE HAZARDS REDUCTION ACT THE RESPONSIBILITY FOR DIFFERENT ACTIVITIES RELATED TO EARTHQUAKE HAZARD REDUCTION IS PRIMARILY ASSIGNED TO FOUR SPECIFIC AGENCIES, ALTHOUGH OTHER AGENCIES PARTICIPATE IN THE PROGRAM IN CONNECTION WITH THEIR OPERATIONAL RESPONSIBILITIES. FEMA IS DESIGNATED AS THE LEAD AGENCY.

EARTHQUAKES ARE NOT UNIQUE TO A PARTICULAR COUNTRY, AND TO A PARTICULAR STATE. THE UNITED STATES HAS BEEN FORTUNATE IN THAT DURING ITS HISTORY THE SEVEREST EARTHQUAKE, WHICH OCCURRED IN NEW MADRID, MISSOURI IN 1811-12, STRUCK AT A TIME WHEN THE POPULATION DENSITY WAS LOW AND THERE WERE FEW MAJOR CONSTRUCTED FACILITIES

ELECTRICAL SUPPLY SYSTEMS. EXISTING STRUCTURES ALSO POSE A PROBLEM DUE TO THE DIFFICULTIES IN ASSESSING LEVELS OF HAZARD AND BALANCING POTENTIAL ECONOMIC AND HUMAN LOSSES AGAINST COSTS OF RETROFITTING AND UPGRADING SUCH STRUCTURES.

THE NSF'S ACTIVITIES RELATED TO EARTHQUAKE HAZARD MITIGATION INCLUDE RESEARCH IN THE EARTH SCIENCES, ENGINEERING, ARCHITECTURE, AND THE SOCIAL SCIENCES. THESE ACTIVITIES ARE SUPPORTED THROUGH THE EARTH SCIENCES DIVISION (EAR) IN THE ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES (AAEO) DIRECTORATE AND THE EARTHQUAKE HAZARD MITIGATION PROGRAM (EHMP) OF THE EMERGING AND CRITICAL ENGINEERING SYSTEMS DIVISION (ECES) IN THE ENGINEERING (ENG) DIRECTORATE.

I WOULD FIRST LIKE TO DESCRIBE SOME OF THE ACTIVITIES CARRIED ON THROUGH THE EARTH SCIENCES DIVISION (EAR) IN THE ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES (AAEO) DIRECTORATE.

SEISMOLOGY AND EARTHQUAKE-RELATED FUNDAMENTAL STUDIES HAVE BEEN OF LONG-TERM INTEREST TO THE EARTH SCIENCES DIVISION AND HAVE CONSTITUTED A SIGNIFICANT PART OF THE DIVISION'S PROGRAM FOR SOME 20 YEARS. THE IMPORTANCE OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM TO THE DIVISION IS IN STRESSING THE IMPORTANCE OF THE RESEARCH TO THE CONCERNED SCIENTIFIC COMMUNITY, AND IN ENSURING GOOD COORDINATION BOTH WITHIN THAT COMMUNITY AND WITH THE OTHER GOVERNMENT AGENCIES INVOLVED.

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AN UNDERSTANDING OF THE FUNDAMENTALS OF THE EARTHQUAKE PHENOMENON AND ASSOCIATED PROCESSES IS ESSENTIAL FOR THE EVENTUAL PREDICTION OF EARTHQUAKES AND DESTRUCTIVE GROUND MOTION. AN INDEPENDENT PROGRAM OF FUNDAMENTAL STUDIES, THEREFORE, PROVIDES THE FRAMEWORK ON WHICH A MORE EMPIRICAL PROGRAM OF EARTHQUAKE PREDICTION CAN BE BASED.

THE EARTH SCIENCES DIVISION HAS SUPPORTED A NUMBER OF PROJECTS TO PROVIDE THE FUNDAMENTAL UNDERSTANDING MENTIONED ABOVE. A FEW HIGHLIGHTS OF THE KIND OF RESEARCH INVOLVED ARE:

- o Rock Physics and Geologic Structure of the San Andreas Fault Zone from Seismic Reflection and Vertical Seismic Profiling - The hydraulic and elastic properties of a fault zone, together with the configuration of the zone as a function of depth, hold the key to a number of questions concerning the earthquake generation process along active faults.

  Earth scientists from the academic community in southern California, whose interests include crustal structure and evolution, have formed a regional consortium (CALCRUST) to apply the seismic reflection technique, in combination with geological and geochemical observations, toward an improved understanding of the subsurface in the southwestern U.S. Members of the consortium are: University of Southern California, California Institute of Technology, University of

CALIFORNIA, SANTA BARBARA, UNIVERSITY OF CALIFORNIA, BERKELEY, SAN DIEGO STATE UNIVERSITY, AND CALIFORNIA STATE UNIVERSITY, LOS ANGELES. A TWO-YEAR PROGRAM BY CALCRUST, INITIATED IN 1984, WILL INCLUDE A STUDY OF THE GEOLOGIC STRUCTURE OF THE SAN ANDREAS FAULT FROM CONVENTIONAL SEISMIC REFLECTION PROFILING AND FROM VERTICAL SEISMIC PROFILING (VSP) IN DEEP BOREHOLES.

IN THIS PROJECT CALCRUST WILL EMPHASIZE THE ACQUISITION OF SEISMIC DATA NEAR THE SAN ANDREAS FAULT ZONE USING A VERTICAL SENSOR STRING EMPLACED IN A DEEP BOREHOLE (UP TO 1500 METERS) IN COMBINATION WITH DATA RECORDED AT THE SURFACE USING MORE CONVENTIONAL METHODS. BOREHOLE OR VSP (VERTICAL SEISMIC PROFILING) EXPERIMENTS PROVIDE A LEVEL OF DETAIL NOT COMMONLY OBTAINED VIA SURFACE ARRAYS ALONE.

o <u>THE EARTHQUAKE PROCESS</u> - IN ORDER TO PREDICT EARTHQUAKES AND ESTIMATE THE DAMAGE THAT MAY BE CAUSED BY A LARGE EARTHQUAKE, ONE NEEDS TO UNDERSTAND THE PHYSICAL PROCESSES OCCURRING AT THE SOURCE OF AN EARTHQUAKE. FROM THIS ONE CAN UNDERSTAND THE PHYSICAL CONDITIONS UNDER WHICH EARTHQUAKES OCCUR AND ONE MAY CALCULATE THE EXPECTED GROUND SHAKING AT ANY PLACE CLOSE TO OR FAR FROM THE EARTHQUAKE SOURCE. UNDER NSF FUNDING, SCIENTISTS AT LAMONT-DOHERTY GEOLOGICAL OBSERVATORY OF COLUMBIA UNIVERSITY HAVE BEEN APPROACHING THIS PROBLEM IN A NOVEL WAY -- I.E., USING A FRACTURE MECHANICS APPROACH TO STUDY THE

RAPID FAULTING PROCESS DURING THE EARTHQUAKE. THE SCIENCE OF FRACTURE MECHANICS IS VERY ADVANCED AND IS USED EXTENSIVELY BY CIVIL, MECHANICAL, AERONAUTICAL AND OTHER ENGINEERS TO STUDY HOW BRIDGES, MACHINES, AIRPLANES, ETC. MAY BREAK UNDER STRESS. LAMONT SCIENTISTS ARE USING THE DEVELOPMENTS MADE IN THIS FIELD AND ARE APPLYING THEM TO THE STUDY OF HOW THE EARTH'S CRUST BREAKS DURING A LARGE EARTHQUAKE.

THE PROBLEM IS STUDIED BY MAKING THEORETICAL MODELS, USING LARGE COMPUTERS, OF THE SPEED WITH WHICH FRACTURES PROPAGATE THROUGH THE EARTH'S CRUST. ONE OF THE IMPORTANT RESULTS FROM THESE INVESTIGATIONS IS A NEW MODEL WHICH MAY EXPLAIN WHY LARGE EARTHQUAKES ALMOST ALWAYS NUCLEATE AT DEPTH NEAR THE BASE OF THE BRITTLE, SEISMOGENIC PORTION OF THE RIGID PLATES COVERING THE EARTH'S SURFACE AND PROPAGATE UPWARD AND ALONG THE PLATE MARGINS. ESSENTIALLY, THE MODEL PREDICTS THAT IF AN EARTHQUAKE NUCLEATES AT SHALLOW DEPTHS IN THE LOW STRENGTH PART OF A FAULT, IT CANNOT PROPAGATE DYNAMICALLY INTO THE HIGHER-STRENGTH DEEPER REGIONS; ONLY AN EARTHQUAKE THAT NUCLEATES IN THE HIGHER STRENGTH PART OF THE FAULT AT DEPTH HAS THE POTENTIAL TO BECOME A LARGE OR GREAT EARTHQUAKE (PROVIDED, OF COURSE, THAT OTHER PARTS OF THE FAULT PLANE ARE CLOSE TO FAILURE). THESE RESULTS MAY HAVE FUTURE PRACTICAL APPLICATIONS.

EARTHQUAKES HAVE, IN A LARGE NUMBER OF CASES, BEEN TRIGGERED BY THE FILLING OF RESERVOIRS. BECAUSE THE IMPOUNDED WATER POSES A POTENTIAL HAZARD, THE MAXIMUM LIKELY SIZE OF SUCH TRIGGERED EVENTS BECOMES A QUESTION OF CRITICAL IMPORTANCE. IN A FEW WELL-STUDIED SEQUENCES, (E.G., LAKE JOCASSEE IN SOUTH CAROLINA) THE EARTHQUAKES LIE WITHIN FOCAL DEPTHS OF LESS THAN A FEW KILOMETERS. IF SO, AND IF THE ABOVE MODEL IS CORRECT, THERE WOULD APPEAR TO BE A LOWER POTENTIAL FOR SEVERE EARTHQUAKE DAMAGE THAN HAS BEEN ANTICIPATED.

RECENT SURVEYS OF THE EARTH SCIENCES BY THE NATIONAL ACADEMY OF SCIENCES (NAS) INCLUDING A COMMITTEE ON SCIENCE, ENGINEERING AND PUBLIC POLICY (COSEPUP) RESEARCH BRIEFING ON THE SOLID EARTH SCIENCES HAVE RECOMMENDED THAT NSF SUPPLEMENT ITS SMALL GRANT RESEARCH PROGRAMS IN EARTH SCIENCES WITH SELECTED LARGER MULTI-INSTITUTIONAL PROJECTS AIMED AT A NEW AND MORE COMPREHENSIVE UNDERSTANDING OF THE CONTINENTAL LITHOSPHERE - THE OUTER, RELATIVELY RIGID LAYER OF THE EARTH, APPROXIMATELY 100 KILOMETERS THICK, AND UNDERLAIN BY LESS RIGID ROCKS.

A BASIC AND MORE ADVANCED UNDERSTANDING OF THE EARTH'S LITHOSPHERE IN GENERAL, AND THE STRUCTURE AND CHARACTERISTICS OF THE CRUST UNDERLYING NORTH AMERICA SPECIFICALLY, COULD RESULT IN IMPORTANT SCIENTIFIC DISCOVERIES. THESE, IN TURN,

COULD LEAD TO BREAKTHROUGHS IN NEW ENERGY SOURCES AND MINERAL DEPOSITS, RESPONSIBLE METHODS OF WASTE DISPOSAL AND ADVANCES IN PREDICTION OF EARTHQUAKES AND VOLCANIC ACTIVITY.

THE EARTH SCIENCES DIVISION HAS ADDED A NEW PROGRAM, THE CONTINENTAL LITHOSPHERE PROGRAM (CLP), TO ADDRESS PROJECTS OF THE TYPE ENVISIONED IN THE NAS REPORTS. SOME AREAS OF RESEARCH WITHIN THIS PROGRAM MAY HAVE APPLICABILITY TO THE NEHRP. ONE SUCH AREA INVOLVES SEISMIC INVESTIGATIONS OF THE CONTINENTAL CRUST. THIS AREA INCLUDES BOTH SEISMIC REFLECTION PROFILING AND SEISMIC REFRACTION STUDIES AND PROVIDES THE MOST DETAILED INFORMATION ON DEEP STRUCTURE. THE REGIONAL CONSORTIUM CALCRUST MENTIONED EARLIER IS AN EXAMPLE OF A PROJECT IN THIS AREA SUPPORTED BY THE CLP. COCORP, THE CORSORTIUM FOR CONTINENTAL REFLECTION PROFILING PROJECT AT CORNELL UNIVERSITY FEATURED IN PREVIOUS YEARS EARTHQUAKE TESTIMONY IS ANOTHER EXAMPLE.

ANOTHER PRIORITY RESEARCH AREA POSSIBLY APPLICABLE TO THE NEHRP AND IDENTIFIED BY THE NAS REPORTS IS THE USE OF MODERN, DIGITAL, WIDE-BAND, WIDE-DYNAMIC-RANGE, SEISMOGRAPH ARRAYS. SUCH ARRAYS, LINKED TO COMPUTERS, CAN PROVIDE HIGH-RESOLUTION IMAGING OF THE CRUST AND DEEPER PARTS OF THE LITHOSPHERE. THEY MAY BE ABLE TO PROVIDE THE DATA NEEDED TO DETERMINE THE PRECISE LOCATION AND MECHANISM OF EARTHQUAKES ANYWHERE ON THE GLOBE IN NEAR REAL TIME USING SATELLITE TELEMETRY. MODERN

DIGITAL DATA PERMIT THE USE OF SOPHISTICATED TOMOGRAPHIC TECHNIQUES (SIMILAR TO CAT SCANS IN MEDICAL SCIENCE) TO MAP THE STRUCTURE (AND POSSIBLE KINEMATICS) OF THE LITHOSPHERE AND DEEPER PARTS OF THE EARTH. NSF WOULD BE COOPERATING IN THIS AREA OF RESEARCH WITH THE U.S. GEOLOGICAL SURVEY WHICH OPERATES THE CURRENT, LARGELY ANALOG, WORLD WIDE STANDARD SEISMOGRAPH NETWORK (WWSSN). THIS NETWORK HAS PROVIDED MUCH VALUABLE DATA FOR BASIC SEISMOLOGICAL RESEARCH OVER THE PAST TWENTY YEARS.

FUNDING FOR THE PROGRAM IN THE AAEJ DIRECTORATE FOLLOWED OPTION B OF THE GUIDELINES SET BY THE Le'o NEWMARK-STEVER REPORT THROUGHOUT THE DURATION OF THOSE GUIDELINES. IN FY 1985 THE PROGRAM WILL BE FUNDED AT $8.4M. THE FUNDING REQUESTED FOR FY 1986 IS $11.0M, THE INCREASE REFLECTING FUNDS REQUESTED FOR THE PRIORITY RESEARCH AREAS MENTIONED ABOVE IN THE CONTINENTAL LITHOSPHERE PROGRAM.

CLOSE COORDINATION AMONG THE PROGRAMS OF THE EARTH SCIENCES DIVISION, EARTHQUAKE ENGINEERING RESEARCH, THE EARTHQUAKE PREDICTION PROGRAM OF THE USGS, AND THE EARTHQUAKE RESEARCH PROGRAMS OF OTHER AGENCIES IS VERY IMPORTANT. THIS IS

ATTAINED BY CLOSE PERSONAL CONTACTS OF PROGRAM PERSONNEL AND BY LIAISON MEMBERSHIP ON EACH OTHER'S ADVISORY AND EVALUATION COMMITTEES.

I WOULD NEXT LIKE TO DESCRIBE SOME OF THE ACTIVITIES CARRIED OUT THROUGH THE EARTHQUAKE HAZARD MITIGATION PROGRAM, IN THE ENGINEERING DIRECTORATE. EARTHQUAKE ENGINEERING RESEARCH ACTIVITIES HAVE EXISTED AT NSF AS A SEPARATELY IDENTIFIED ACTIVITY SINCE APPROXIMATELY 1964. AS REORGANIZATIONS WITHIN NSF HAVE OCCURRED OVER THE YEARS, THE EARTHQUAKE HAZARD MITIGATION PROGRAM PROGRESSED FROM ITS INITIATION AS A PART OF AN INTEGRATED NATURAL HAZARDS RESEARCH ACTIVITY TO A SEPARATE PROGRAM IN THE DIRECTORATE FOR RESEARCH APPLIED TO NATIONAL NEEDS (RANN), THE DIRECTORATE FOR APPLIED SCIENCE AND RESEARCH APPLICATIONS, THE DIRECTORATE FOR ENGINEERING AND APPLIED SCIENCE, AND THE DIRECTORATE FOR ENGINEERING. IN A RECENT REORGANIZATION OF THE ENGINEERING DIRECTORATE, THE EARTHQUAKE HAZARD MITIGATION PROGRAM WAS PLACED IN THE CRITICAL ENGINEERING SYSTEMS SECTION OF THE DIVISION OF FUNDAMENTAL RESEARCH FOR EMERGING AND CRITICAL ENGINEERING SYSTEMS. WITHIN THIS NEW ORGANIZATIONAL STRUCTURE THE EARTHQUAKE HAZARD MITIGATION PROGRAM IS A VITAL PART ALONG WITH THE COMPANION PROGRAMS, NATURAL AND MAN-MADE HAZARDS, AND SYSTEMS

ENGINEERING FOR LARGE STRUCTURES. THEY SHARE A COMMON CONCERN FOR THE DEVELOPMENT OF AN IMPROVED KNOWLEDGE BASE FOR SOLVING SUCH PROBLEMS AS: POTENTIAL DESTRUCTION OR LOSS OF SERVICE; DETERIORATION FROM AGE; LONG-TERM USE OR EXPOSURE; ASSESSMENT FOR SAFETY OR SERVICEABILITY; REDUCTION OF FUTURE MAINTENANCE COSTS; AND INNOVATION IN THE POSSIBLE FUTURE CHANGED USAGE OF CONSTRUCTED FACILITIES IN THE UNITED STATES.

IN TERMS OF ECONOMIC IMPORTANCE, THE YEARLY CAPITAL CONSTRUCTION COSTS IN THE U.S. EXCEED $500 BILLION AND ARE THE LARGEST SINGLE ITEM REPRESENTED IN THE ECONOMIC INDICATORS PUBLISHED BY THE DEPARTMENT OF COMMERCE. THE TOTAL ACCUMULATED CONSTRUCTED CAPITAL INVESTMENT IN THE U.S. IS THUS VERY SUBSTANTIAL AND IS A VITAL ELEMENT IN THE FUNCTIONING OF ECONOMIC ACTIVITY AND HEALTH OF THE COUNTRY.

THE EARTHQUAKE HAZARDS MITIGATION PROGRAM HAS PREVIOUSLY BEEN REPORTED UNDER THREE PROGRAM SUBELEMENTS: SITING, DESIGN, AND SOCIETAL RESPONSE. THESE SAME SUBELEMENTS WERE USED IN PREPARING THE FY 1986 BUDGET. HOWEVER, WITHIN THE CRITICAL ENGINEERING SYSTEMS SECTION, THE EARTHQUAKE HAZARDS MITIGATION PROGRAM HAS BEEN DIVIDED INTO FOUR NEW SUBELEMENTS WHICH TAKE INTO ACCOUNT RESEARCH EFFORTS NOW SUCCESSFULLY COMPLETED AND THE ELIMINATION OF THE SOCIETAL RESPONSE TITLE AS A SUBELEMENT OF THIS PROGRAM. THESE NEW SUBELEMENTS ARE INTENDED TO EMPHASIZE AREAS OF RESEARCH WHICH ARE CURRENTLY MOST IMPORTANT

FOR EARTHQUAKE ENGINEERING. THESE PROGRAM ELEMENTS AND THEIR GENERAL OBJECTIVES ARE:

o SITING AND GEOTECHNICAL SYSTEMS

THIS ADDRESSES THE FUNDAMENTAL ENGINEERING ISSUES RELATED TO EARTHQUAKE GROUND MOTION AND ESTIMATES THE EFFECTS OF GEOLOGIC STRUCTURES, INCLUDING SURFACE AND SUBSURFACE SOIL AND ROCK SYSTEMS. PRIMARY RESEARCH AREAS ARE STRONG MOTION RESEARCH, GEOTECHNICAL SYSTEMS STABILITY, TSUNAMI SYSTEMS ENGINEERING AND LIFELINE SYSTEMS.

o STRUCTURAL SYSTEMS

THIS ADDRESSES FUNDAMENTAL ENGINEERING ISSUES RELATED TO THE CONVERSION OF BASIC SCIENTIFIC SEISMOLOGICAL AND GROUND-MOTION DATA INTO BASIC ENGINEERING SEISMIC LOADINGS; THE DEVELOPMENT OF INNOVATIVE AND PRACTICAL ANALYTIC METHODS TO PREDICT THE RESPONSE OF CONSTRUCTED SYSTEMS TO EARTHQUAKES, THE DEVELOPMENT OF BASIC ENGINEERING INFORMATION ON THE DYNAMIC RESISTANCE OF NEW AND EXISTING CONSTRUCTED SYSTEMS, ADVANCES IN RISK ANALYSIS METHODOLOGY, AND THE IDENTIFICATION AND DEVELOPMENT OF TEST FACILITIES WHICH ARE IMPORTANT TO UNDERSTANDING AND PREDICTING THE SEISMIC BEHAVIOR OF CONSTRUCTED SYSTEMS.

o ARCHITECTURAL AND MECHANICAL SYSTEMS

THIS ADDRESSES FUNDAMENTAL ARCHITECTURAL AND MECHANICAL SYSTEMS WHICH GENERALLY COMPRISE PORTIONS OF STRUCTURES AND FACILITIES WHICH ARE NOT TAKEN INTO ACCOUNT WHEN EVALUATING THE STRENGTH AND RESISTANCE OF A STRUCTURE TO EARTHQUAKE FORCES. ALSO INCLUDED ARE ITEMS SUCH AS COMPUTERS, BUILDING CONTENTS, MECHANICAL EQUIPMENT AND ELECTRICAL DISTRIBUTION EQUIPMENT.

o EARTHQUAKE SYSTEMS INTEGRATION

THIS ADDRESSES FUNDAMENTAL ENGINEERING ISSUES CONCERNING MORE EFFECTIVE APPLICATION OF KNOWLEDGE BY ENGINEERS, ARCHITECTS, PLANNERS, AND OTHER PRACTITIONERS TO MITIGATING, PREPARING FOR AND RECOVERING FROM EARTHQUAKES. RESEARCH SUPPORTED INCLUDES INNOVATIVE EFFORTS WHICH STIMULATE THE FLOW OF KNOWLEDGE FROM KNOWLEDGE PRODUCING-SYSTEMS TO KNOWLEDGE USING-SYSTEMS.

I WOULD LIKE TO HIGHLIGHT A FEW ACTIVITIES WHICH HAVE BEEN CARRIED ON UNDER THE NSF EARTHQUAKE HAZARD MITIGATION PROGRAM.

o <u>MASONARY RESEARCH</u> - THE LARGE NUMBER OF BUILDINGS CONSTRUCTED FROM UNREINFORCED MASONRY ARE A SIGNIFICANT

TO SUSTAIN DAMAGE. IN OTHER MAJOR EARTHQUAKES WE HAVE OFTEN BEEN FORTUNATE IN THAT THE EARTHQUAKE STRUCK AT A TIME WHEN POPULATION EXPOSURE TO HIGH-RISK SITUATIONS WAS AT A MINIMUM. THUS THE AVERAGE NUMBER OF PERSONS WHO HAVE LOST THEIR LIVES DUE TO EARTH SHAKING DURING U.S. HISTORY IS RELATIVELY LOW IN COMPARISON WITH OTHER SEISMICALLY ACTIVE COUNTRIES. LOSS OF LIFE DUE TO A SINGLE EARTHQUAKE EVENT IN SOME COUNTRIES HAS EXCEEDED 500,000. THE COMPARATIVELY LOW NUMBER IN THE U.S., HOWEVER, SHOULD NOT LEAD US TO BE COMPLACENT, AS POPULATION DENSITIES IN SEISMIC PRONE AREAS ARE INCREASING. THIS CAN LEAD TO AN INCREASED LEVEL OF RISK, PARTICULARLY IN CONNECTION WITH EXISTING BUILDINGS, AND OTHER FACILITIES CONSTRUCTED BEFORE A KNOWLEDGE BASE ABOUT EARTHQUAKE ENGINEERING WAS AVAILABLE. ALTHOUGH OUR KNOWLEDGE OF HOW TO DESIGN NEW STRUCTURES TO RESIST THE EFFECTS OF EARTHQUAKES HAS VASTLY IMPROVED AS A RESULT OF BOTH THE NSF RESEARCH PROGRAMS AND THOSE OF OTHER AGENCIES IN THE EARTHQUAKE HAZARD REDUCTION ACT, THERE ARE STILL MANY GAPS AND INCOMPLETE DATA ON WHICH TO BASE DESIGNS. A MAJOR THRUST IN PAST YEARS' RESEARCH WAS TO DEVELOP METHODS AND INFORMATION WHICH ASSURE THAT CONSTRUCTED FACILITIES WOULD NOT SUFFER GROSS FAILURES OF A LIFE-THREATENING NATURE. FOR MOST TYPES OF STRUCTURES THE KNOWLEDGE BASE WHICH HAS BEEN DEVELOPED THROUGH NSF RESEARCH MAKES IT POSSIBLE TO DESIGN AGAINST SUCH GROSS FAILURES IN NEW STRUCTURES. A SERIOUS PROBLEM STILL EXISTS, HOWEVER, IN PREDICTING AND DESIGNING AGAINST SERIOUS ECONOMIC LOSSES IN MANY NEW STRUCTURES AND AGAINST LOSS OF SERVICE OF VITAL LIFE-LINE FACILITIES SUCH AS WATER AND

SEISMIC HAZARD IN MANY PARTS OF THE U.S. AND IN OTHER COUNTRIES. AS ONLY MINIMAL BASIC ENGINEERING STUDIES HAVE EVER BEEN CARRIED OUT UNDER STATIC, LET ALONE DYNAMIC, LOADING CONDITIONS, THE KNOWLEDGE-BASE FOR MASONRY SYSTEMS IS DANGEROUSLY DEFICIENT. SUCH CONSTRUCTION PRESENTS A REAL DILEMMA. BECAUSE MASONRY CONSTRUCTION HAS BEEN USED FOR PERHAPS THOUSANDS OF YEARS, IT IS GENERALLY ASSUMED BY THE PUBLIC THAT WE MUST HAVE A COMPLETE KNOWLEDGE OF THE BEHAVIOR OF SUCH SYSTEMS. UNFORTUNATELY THE KNOWLEDGE BASE WHICH HAS DEVELOPED IS PRIMARILY EMPIRICAL INFORMATION ACCUMULATED OVER TIME AND THIS INFORMATION PROVIDES INADEQUATE GUIDANCE FOR EXTRAPOLATING TO DIFFERENT CONDITIONS. THUS, IN ORDER TO ASSESS THE POTENTIAL HAZARD OF UNREINFORCED MASONRY SYSTEMS AND TO DEVELOP INNOVATIVE WAYS TO REINFORCE AND RETROFIT SUCH SYSTEMS, AN IMPROVED UNDERSTANDING OF THEIR BEHAVIOR IS NEEDED. A FIRST STEP IN THAT DIRECTION WAS ACHIEVED THROUGH AN NSF RESEARCH PROGRAM WHICH STUDIED UNREINFORCED MASONRY SYSTEMS SUCH AS MIGHT OCCUR IN TYPICAL LOW-RISE STRUCTURES. THE STUDY WAS CARRIED UNDER A CONSORTIUM OF INVESTIGATORS (THE A-B-K GROUP) FORMED FOR THE PURPOSE. AN INTERESTING OUTCOME OF THE STUDY WAS THAT FOR A MAJORITY OF UNREINFORCED MASONRY STRUCTURES, HORIZONTAL FORCES DUE TO EARTHQUAKE MOTIONS ARE TRANSFERRED THROUGH HORIZONTAL WOOD DIAPHRAGMS (I.E. FLOOR SYSTEMS), AND THE KNOWLEDGE OF THE HORIZONTAL LOAD TRANSFER MECHANISMS FOR WOOD DIAPHRAGMS WAS AS INADEQUATE AS THAT FOR MASONRY. THUS

IN ORDER TO STUDY THE MASONRY PROBLEM, A PILOT EFFORT ON WOOD DIAPHRAGMS HAD TO BE CONDUCTED.

AS A FIRST PHASE IN ACQUIRING KNOWLEDGE, THE PROGRAM HAS BEEN EXTREMELY SUCCESSFUL AND THE KNOWLEDGE DEVELOPED HAS ALREADY BEEN INCORPORATED IN NEW METHODS FOR THE RETROFIT OF CERTAIN TYPES OF EXISTING UNREINFORCED MASONRY STRUCTURES. THIS NEW APPROACH PROVIDES SIGNIFICANT SAVINGS OVER METHODS PREVIOUSLY CONSIDERED AND WILL SIMPLIFY THE UPGRADING OF UNREINFORCED MASONRY STRUCTURES IN LARGE AREAS OF THE U.S. WHICH FACE LOWER-FREQUENCY SEISMIC RISKS. THE TRANSFER OF THIS INFORMATION TO THOSE WHO MIGHT BENEFIT FROM OR USE SUCH INFORMATION IS BEING ENCOURAGED THROUGH SUPPORT OF WORKSHOPS AND CONFERENCES.

o <u>LEARNING FROM DISASTERS</u> - THE NSF HAS ARRANGEMENTS THROUGH THE NATIONAL ACADEMY FOR ENGINEERING AND THE EARTHQUAKE ENGINEERING RESEARCH INSTITUTE (EERI), FOR DISPATCHING INVESTIGATOR TEAMS TO AREAS DAMAGED BY NATURAL HAZARDS TO CAPTURE PERISHABLE INFORMATION THAT RAPIDLY DISAPPEARS DURING RESCUE AND CLEAN-UP OPERATIONS. SUCH INFORMATION IS ABSOLUTELY ESSENTIAL FOR IMPROVING THE KNOWLEDGE BASE FOR THE BEHAVIOR OF CONSTRUCTED FACILITIES UNDER TRUE SIMULATED, LOADING CONDITIONS. THIS PROVIDES VERIFICATION OF COMPUTER-BASED ANALYTIC METHODS AND BASED EXPERIMENTAL STUDIES.

IN THE LAST FEW WEEKS A TEAM WAS DISPATCHED TO CHILE TO STUDY THE EFFECTS OF AN EARTHQUAKE WHICH CAUSED EXTENSIVE STRUCTURAL AND GROUND DAMAGE ON THE NIGHT OF MARCH 5, 1985. THIS TEAM IS A COOPERATIVE ONE INVOLVING NAE, EERI AND A NUMBER OF PRIVATE COMPANIES.

o CONTAINED EXPLOSIVE TESTING - WORKING UNDER NSF SUPPORT A NEW METHOD HAS BEEN DEVELOPED TO SIMULATE EARTHQUAKE GROUND MOTION. THE DEVELOPMENT OF THE IN-PLACE METHOD HAS THE POTENTIAL TO PROVIDE A NEW DIMENSION TO OUR CAPABILITIES TO TEST AND UNDERSTAND THE GROUND MOTIONS, AND RESULTING DAMAGE TO STRUCTURES AND LIFELINE SYSTEMS. THIS TECHNIQUE CAN BE USED FOR FULL SCALE TESTS UNDER ACTUAL CONDITIONS. THE TECHNIQUE ESSENTIALLY INVOLVES PRODUCING EARTHQUAKE LIKE GROUND MOTIONS BY SIMULTANEOUS DETONATION OF A BURIED ARRAY OF VERTICAL LINE SOURCES. THE KEY FEATURE OF EACH LINE SOURCE IS A CYLINDRICAL TUBE SURROUNDED BY A RUBBER MEMBRANE INTO WHICH EXPLOSIVE GASES ARE VENTED. IN ORDER TO PROVIDE VERIFICATION OF THE TECHNIQUE, THEORETICAL STUDIES ARE BEING MADE OF THE GROUND MOTIONS PRODUCED BY THE EXPLOSIVE ARRAY AND COMPARED TO GROUND MOTION PRODUCED IN THE NEAR FIELD BY LARGE EARTHQUAKES. THIS METHOD, IF SUCCESSFUL, OPENS UP THE POSSIBILITY OF IN-PLACE FULL SCALE TESTING AT HIGH LEVELS OF GROUND MOTION, WITH MINIMAL DISTURBANCE TO THE ENVIRONMENT.

o SMART STRONG-MOTION ARRAY - ALTHOUGH SEISMOLOGICAL STUDIES

PROVIDE A BASIS FOR ESTABLISHING THE POTENTIAL FREQUENCY OF EARTHQUAKES AND THE LOCATIONS OF PREVIOUS EARTHQUAKES, THEY DO NOT PROVIDE ONE VITAL PIECE OF ENGINEERING INFORMATION. THIS IS THE INTENSITY OF THE ACTUAL STRONG-GROUND MOTION WHICH TAKES PLACE AT OR NEAR THE SURFACE OF THE GROUND AT SPECIFIC POINTS. THE PICTURE OF GROUND MOTION INTENSITIES CAN BECOME QUITE COMPLEX DUE TO MODIFICATION OF TRANSMITTED WAVE ENERGY BY VARIATIONS IN SOIL PROPERTIES AND FROM REFLECTED, REFRACTED AND RE-RADIATED WAVE ENERGY. STRONG-MOTION MEASUREMENTS MADE AT SPECIFIC POINTS HAVE INCREASED IN NUMBER IN RECENT YEARS BUT THE BULK OF THESE MEASUREMENTS ARE POINT MEASUREMENTS WHICH DO NOT PROVIDE INFORMATION ON THE SPATIAL CORRELATION OR VARIATION OF GROUND MOTION OVER DISTANCES OF ENGINEERING RATHER THAN GEOLOGICAL INTEREST.

IN ORDER TO DEVELOP IMPROVED KNOWLEDGE OF SPATIAL CORRELATIONS OF STRONG GROUND MOTIONS NEEDED FOR DESIGN OF LIFE-LINE SYSTEMS, AND IN ORDER TO ESTABLISH THE PROBABLE LEVEL OF NATURAL VARIATION IN LOCAL STRONG GROUND MOTIONS, PLANS HAVE BEEN DEVELOPED FOR A COORDINATED ARRAY OF STRONG-MOTION INSTRUMENTS WHICH COULD RECORD SUCH INFORMATION. IN ORDER TO OPTIMIZE THE RECOVERY OF DATA IT IS DESIRABLE TO PLACE SUCH AN ARRAY IN A RATHER ACTIVE EARTHQUAKE AREA. SUCH A SITE HAS BEEN FOUND IN TAIWAN WHERE BOTH AN ACTIVE SITE AND ONE OF INTEREST FROM A SOIL

MECHANICS POINT OF VIEW EXISTS. AN INSTRUMENT ARRAY KNOWN AS THE "SMART STRONG-MOTION ARRAY" HAS BEEN INSTALLED ON THIS SITE. THE INITIAL INSTALLATION IS PRIMARILY A SURFACE ARRAY WHICH IS NETWORKED TOGETHER TO PROVIDE A MINI-TOMOGRAPHIC (AS COMPARED TO THE CRUSTAL STUDIES PREVIOUSLY DESCRIBED) PICTURE OF STRONG GROUND MOTIONS OVER THE AREA OF THE ARRAY. A NUMBER OF SIGNIFICANT STRONG-GROUND MOTIONS HAVE ALREADY BEEN CAPTURED BY THE ARRAY.

FUTURE PLANS ARE TO INSTALL "DOWNHOLE" INSTRUMENTATION WHICH WILL PROVIDE A THIRD DIMENSION TO THE DATA CAPTURED BY THE ARRAY. THIS WILL PROVIDE MUCH BETTER DATA ON THE SPATIAL PROPERTIES OF STRONG GROUND MOTION AND A BETTER BASIS FOR ENGINEERING CHARACTERIZATION OF STRONG GROUND MOTION.

o <u>COMPUTER UTILIZATION</u> - ONE PRODUCT OF MANY NSF RESEARCH PROGRAMS HAS BEEN INNOVATIVE APPROACHES FOR USING COMPUTERS IN THE ANALYSIS AND SOLUTION OF ENGINEERING PROBLEMS. A STRONG EFFORT HAS BEEN MADE TO MAKE THESE PROGRAMS AVAILABLE TO POTENTIAL USERS. SINCE 1971 THE EARTHQUAKE HAZARDS MITIGATION PROGRAM HAS SUPPORTED THE NATIONAL INFORMATION SERVICE FOR EARTHQUAKE ENGINEERING. ONE ACTIVITY OF THIS SERVICE IS TO MAKE AVAILABLE COMPUTER SOFTWARE, DEVELOPED UNDER PUBLIC SUPPORT, WHICH IS RELATED TO EARTHQUAKE AND NATURAL HAZARD PROBLEMS. ALTHOUGH MOST OF THE SOFTWARE IS

NOT IN A "COMMERCIAL" FORM, THE SOFTWARE PRESENTS NEW CONCEPTS AND THE "CUTTING EDGE" OF RESEARCH. NUMEROUS FIRMS, GOVERNMENT AGENCIES AND OTHER RESEARCHERS HAVE USED THIS SERVICE TO OBTAIN NEW COMPUTATIONAL DEVELOPMENTS WHICH ARE THEN INCORPORATED INTO OTHER PROGRAMS, MANY OF WHICH FORM NEW CAPABILITIES. AS A RESULT OF THIS WORK A MAJORITY OF THE EARTHQUAKE ENGINEERING COMPUTER ANALYSIS AND SOFTWARE PROGRAMS IN THE U.S. AND MANY OTHER COUNTRIES ARE BASED ON OR INFLUENCED BY NSF SUPPORTED EFFORTS.

RECENT ADVANCES IN COMPUTATIONAL EQUIPMENT ARE MAKING IT FEASIBLE TO CARRY OUT ANALYSES WHICH WERE NOT PREVIOUSLY POSSIBLE. FOR EXAMPLE, ONE RECENT COMPUTER PROGRAM, COMBAT, DEVELOPED WITH NSF SUPPORT WILL MAKE IT POSSIBLE TO ROUTINELY PERFORM 3-DIMENSIONAL ANALYSES FOR BUILDING STRUCTURES. THE PROGRAM IS NOW BEING USED AND EVALUATED BY A NUMBER OF GROUPS. THERE IS NOW A HIGH PROBABILITY THAT A USERS GROUP WILL BE FORMED TO CONTINUE DEVELOPMENT OF THIS IMPORTANT TOOL WITHOUT REQUIRING SUBSTANTIAL FURTHER GOVERNMENT SUPPORT.

o <u>International Cooperative Research</u> - A strong feature of the Earthquake Hazard Mitigation Program is a high level of international cooperation. Such cooperation has synergistic effects in which the sum of the two efforts conducted cooperatively is much more effective than the sum of two individual efforts.

For example, NSF has initiated cooperative research program, in areas around the world which have the highest probability for large earthquakes in the near future. Because of our unique expertise on strong motion instruments and data analysis, we initiated programs to install ground instrumentation and collect strong motion data in earthquake prone areas in Taiwan, PRC, India and Mexico. The results from these dense instrument arrays, as I have mentioned before, have provided a new insight into the ground motion variations and the significance of geological conditions and soil characteristics. Because of these cooperative programs, we now have a better data base than in the previous years to verify the predictive analysis results and earthquake engineering evaluations. The data from the Taiwan array on ground motion variations within the land area of typical foundations, lifeline earthquake engineering data from PRC cooperative research, and the comparison of data from digital instruments installed in Mexico are some

EXCELLENT EXAMPLES OF UNIQUE RESULTS DERIVED FROM THESE COOPERATIVE ACTIVITIES FOR USE IN THE UNITED STATES.

SIMILAR COOPERATIVE ENDEAVORS WITH JAPAN HAVE RESULTED IN THE DESIGN, FABRICATION AND TESTING OF LARGE EXPERIMENTAL SYSTEMS FOR EARTHQUAKE ENGINEERING EVALUATIONS OF STRUCTURES BUILT WITH U.S. AND JAPAN DESIGN APPROACHES AND SPECIFICATIONS.

I WOULD LIKE TO REVIEW WITH YOU FUTURE PLANS FOR THE EARTHQUAKE HAZARD MITIGATION PROGRAM. AS YOU HAVE ALREADY HEARD, THE PROGRAM HAS BEEN RESTRUCTURED TO HIGHLIGHT CRITICAL AREAS OF RESEARCH AND HAS BEEN INCORPORATED IN A NEW SECTION OF THE ENGINEERING DIRECTORATE. THIS IS INTENDED TO TAKE A MORE INTEGRATED APPROACH TOWARD DEVELOPING AN IMPROVED KNOWLEDGE BASE FOR DESIGNING, ASSESSING, PRESERVING, UPGRADING, AND ENHANCING CONSTRUCTED FACILITIES, AND TOWARD OPTIMIZING PERFORMANCE AND LIFE-CYCLE COSTS FOR THESE FACILITIES.

AT THE PRESENT TIME WE ARE ENGAGED IN AN INTERNAL SYSTEMS ANALYSIS OF THE CONTENT OF THE EARTHQUAKE HAZARD MITIGATION

RESEARCH PROGRAM AT NSF. THIS CONSISTS OF EVALUATING THE RELATIONSHIP OF THE INDIVIDUAL PROJECTS TO EACH OTHER, AND TO THE OVERALL GOAL OF EARTHQUAKE MITIGATION.

WE ALSO PLAN AN EXTERNAL SYSTEMS ANALYSIS OF THE EARTHQUAKE HAZARD MITIGATION RESEARCH PROGRAM AT NSF BY AN INDEPENDENT CONTRACTOR. THIS WILL EVALUATE THE OVERALL PROGRAM IN RELATIONSHIP TO POTENTIAL HAZARDS, THE ACTIVITIES OF THE OTHER FEDERAL AGENCIES, AND TO OTHER NATURAL AND MAN-MADE HAZARDS THAT INFLICT SEVERE LOSSES AND SUFFERING ON THE PUBLIC. WE EXPECT THE RESULTS TO BECOME AVAILABLE WITHIN A YEAR.

THE RESULTS OF NSF FUNDED RESEARCH IN EARTHQUAKE ENGINEERING ARE OFTEN IMPORTANT TO STATES AND TOWNS AS THEY DEVELOP NEW CODES. IN ORDER TO ACCELERATE THE EXCHANGE OF KNOWLEDGE BETWEEN THE RESEARCH COMMUNITY AND THE USER COMMUNITY, WE WOULD LIKE TO EXPLORE PLANS FOR ESTABLISHING A JOINTLY FUNDED RESEARCH CENTER AT A UNIVERSITY FOR THE STUDY OF MITIGATION OF EARTHQUAKE HAZARDS. SUCH A CENTER WILL ALSO ENABLE THE RESEARCH COMMUNITY TO CONDUCT A LARGE COHERENT PROJECT THAT INDIVIDUAL RESEARCHERS CANNOT PURSUE.

ONE SPECIFIC ITEM WHICH I WOULD LIKE TO MENTION CONCERNS THE SOCIETAL RESPONSE ELEMENT AS ORIGINALLY PRESENTED IN THE BUDGET.

THIS ELEMENT OF THE EARTHQUAKE HAZARD MITIGATION PROGAM HAS A NUMBER OF RESEARCH ACCOMPLISHMENTS TO SHOW IN SOME OF THE PRINCIPAL AREAS OF INTEREST.

MITIGATION AND PREPAREDNESS - WE HAVE ACHIEVED SIGNIFICANT ADVANCES IN UNDERSTANDING:

- o THE INFLUENCE OF HAZARD PERCEPTION ON COMMUNITY MITIGATION PREPAREDNESS DECISIONS
- o HOW SEISMIC BUILDING CODES AND LAND USE PLANS ARE ADOPTED
- o THE EFFECTIVENESS OF HAZARD INSURANCE PROGRAMS AND OTHER TYPES OF PROTECTION.

DISASTER IMPACTS AND RESPONSES - MAJOR ADVANCES HAVE BEEN MADE IN UNDERSTANDING:

- o DIFFERENTIAL IMPACTS OF DISASTERS ON VARIOUS POPULATION GROUPS SUCH AS MINORITIES AND THE ELDERLY
- o THE NATURE OF COMMUNITY RECOVERY FROM DISASTER

INFORMATION DISSEMINATION AND WARNING - MUCH HAS BEEN LEARNED ABOUT:

- o HOW POPULATIONS RESPOND TO DISASTER WARNINGS AND FORECASTS
- o SOCIAL AND INSTITUTIONAL BARRIERS TO MORE EFFECTIVE RESPONSES.

THERE IS EVIDENCE THAT BOTH PUBLIC AND PRIVATE GROUPS ARE USING THE KNOWLEDGE PRODUCED BY RESEARCHERS FUNDED BY NSF IN THE AREA OF SOCIETAL RESPONSES. SOME OF THE KNOWLEDGE PRODUCED ON MITIGATION, PREPAREDNESS, DISASTER IMPACTS AND HUMAN RESPONSES IS NOW REFLECTED IN THE PLANS, PROCEDURES, AND TRAINING PROGRAMS OF THE FEDERAL EMERGENCY MANAGEMENT AGENCY, THE AMERICAN NATIONAL RED CROSS AND THE CALIFORNIA SEISMIC SAFETY COMMISSION. ALSO RESULTS FROM RESEARCH ON HAZARD INFORMATION DISSEMINATION AND DISASTER WARNING HAVE FOUND THEIR WAY INTO ORGANIZATIONS WITH WARNING RESPONSIBILITIES SUCH AS THE U.S. GEOLOGICAL SURVEY, THE NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION AND THE NATIONAL ASSOCIATION OF BROADCASTERS.

RESEARCH IN THE AREA OF SOCIETAL RESPONSE HAS BEEN REDIRECTED AND REFOCUSED ON THE NATURE OF THE TECHNOLOGY DELIVERY SYSTEM IN EARTHQUAKE MITIGATION, ON INSTITUTIONAL ROLES AND INTERACTIONS, AND ON SYSTEMS INTEGRATION.

FUNDING FOR THE EARTHQUAKE HAZARD MITIGATION PROGRAM IN THE DIRECTORATE FOR ENGINEERING WILL TOTAL $17.2M FOR FY 85. THE FUNDING REQUESTED FOR FY 86 IS $18.2M WHICH INCLUDES $15.4M IN THE EARTHQUAKE HAZARD MITIGATION PROGRAM, $1.5M IN OTHER ENGINEERING ACTIVITIES APPLICABLE TO EARTHQUAKE HAZARD MITIGATION, AND $.5M IN THE USE OF COMPUTERS FOR MODELING. THE FUNDING REQUESTED FOR FY 86 IN THE AAEO DIRECTORATE IS $11.0M.

FEASIBILITY STUDIES FOR FUTURE LARGE-SCALE TEST FACILITIES NEEDED TO ANSWER OTHER EARTHQUAKE ENGINEERING PROBLEMS WILL BE CONTINUED, HOWEVER THESE WILL NEED TO BE COST SHARED AND MAINTAINED BY STATES THAT WILL BENEFIT THE MOST FROM EARTHQUAKE HAZARD MITIGATION RESEARCH.

U.S. EARTHQUAKE ENGINEERS ARE AMONG THE BEST IN THE WORLD. AN OBJECTIVE OF THE EARTHQUAKE HAZARD MITIGATION PROGRAM IS TO CONTINUE SUCH SCIENTIFIC AND TECHNICAL LEADERSHIP THROUGH THE CONTINUED DEVELOPMENT OF FUNDAMENTAL ENGINEERING KNOWLEDGE PRIMARILY AT U.S. UNIVERSITIES. THEY HAVE THE RESPONSIBILITY OF PROVIDING THE NATION WITH THE NECESSARY PEOPLE TRAINED IN THE KNOWLEDGE OF EARTHQUAKE HAZARD MITIGATION.

G/D Ref
Apr 15 12 29 PM '84

Nam Pyo Suh

Biographical Sketch

Nam P. Suh is a Professor of Mechanical Engineering at the Massachusetts Institute of Technology, Cambridge, Massachusetts. He is also Director of the Laboratory for Manufacturing and Productivity which is the center for productivity and manufacturing research and education at the Institute. He also has been serving as the Director of the MIT-Industry Polymer Processing Program since its founding in 1973. He is also a member of the Engineering Council of the School of Engineering at M.I.T. He was also Head, Mechanics and Materials Division of the Department of Mechanical Engineering.

Prior to joining the MIT faculty as an Associate Professor of Mechanical Engineering (1970-1975), he was on the faculty at the University of South Carolina, Columbia S.C. His industrial experience includes four years of employment, (1961-65), with USM Corporation, and two years of part-time employment with Guild Plastics, Inc. (1958-60).

He graduated from the Browne and Nichols School in Cambridge, Massachusetts in 1955 and entered MIT where he earned his S.B. and S.M. degrees in 1959 and 1961, respectively. He received his Ph.D. from Carnegie-Mellon University in 1964 under a special fellowship established by the USM Corporation.

His current fields of research are manufacturing, tribology, materials processing, special materials, and design. Among the accomplishments in these fields are developments of new advanced cutting tools, the mixalloying process, the delamination theory of wear, the introduction of the axioms for design and manufacturing, a new NDE technique based on the charge decay concept, development of wear resistant materials, a new friction theory, and many new and commercially successful polymer processing techniques such as the USM process, foam lamination process, and electrical-mechanical hybrid mixing. He also introduced the concept of thermo-mechanical effects in the solid phase reaction and a theory for super rate buring of solid propellants. Over 130 publications and 25 patents have resulted from his work in addition to a text book by Suh and Turner entitled Elements of the Mechanical Behavior of Solids, McGraw-Hill Book Publishing Company and Scripta Technica Publishing Company, and a reference book by Suh on "Tribophysics" to be published by Prentice-Hall. A special issue of the Journal Wear was devoted to his research on the delamination theory of wear which was also published in monograph form. He has given over 50 invited lectures at various universities and institutions throughout the world.

In 1973 he founded a cooperative research program between MIT and industry which has since become a model for similar efforts in the United States and several other countries. The concept was also used in enacting the Stevenson-Wydler Technology Innovation Act of 1981.

He is the recipient of the 1976 Gustus L. Larson Memorial Award of the American Society of Mechanical Engineers and Pi Tau Sigma. His paper on the delamination theory of wear was selected as a Citation Classic by the Institute for Scientific Information. In 1981 he and his students received a Best Paper Award from the Society of Plastics Engineers. He is also the recipient of the 1982 Blackall Award of A.S.M.E.

Professor Suh is serving as Director of Surtech Corporation of New Hampshire, Director of Intelitec Corporation, and the Chairman of the Board of Axiomatics Corporation and Mixalloy Corporation. He has been a consultant for many firms and government agencies. He is serving on the Editorial Board of Polymer Processing, Science Board of Macrochem Corporation, Technical Planning Committee of A.S.M.E. and as the Chairman of the Productivity Committee of A.S.M.E. He is also the Editor of Robotics and Computer Integrated Manufacturing.

He is a member of ASME, SPE, Pi Tau Sigma, Phi Kappa Phi, Sigma Xi and C.I.R.P. He is listed in Who's Who in America, Who's Who in Technology, 5000 of World's Leaders, etc.

He was born in Korea in 1936 and immigrated to the United States of America with his family in 1954. He is a U.S. citizen and married to the former Young J. Surh. They have four daughters.

Mr. WALGREN. Thank you very much, Dr. Suh. We appreciate that testimony.

Let's turn to Mr. Kammer, and we will be able to complete that testimony and then we will have to break to respond to those bells. But I am sure we will be able to complete your testimony and then come back for some discussion.

Mr. Kammer

STATEMENT OF RAYMOND G. KAMMER, DEPUTY DIRECTOR, NATIONAL BUREAU OF STANDARDS, ACCOMPANIED BY DR. RICHARD N. WRIGHT, DIRECTOR, CENTER FOR BUILDING TECHNOLOGY

Mr. KAMMER. Thank you, sir. I am Ray Kammer, Deputy Director of the National Bureau of Standards. With me is Dr. Dick Wright, who is the Director of the Center for Building Technology. This is where the earthquake hazard reduction activities of the National Bureau of Standards are in fact undertaken.

The proposed budget for the National Bureau of Standards for fiscal year 1986 includes some large program changes of about $33 million on a budget of $120 million, $16.5 million in increases and $16.5 million in decreases. One of the decreases proposed is the termination of the Center for Building Technology. This would include stopping NBS efforts in earthquake hazard reduction.

This action is included in the President's budget for two reasons: First of all, to allow NBS to undertake new programs without increasing the NBS budget; and second, to implement the administration's policy of disengaging the Federal Government from areas in which State and local governments have primary responsibility. Building and safety codes have traditionally been within the purview of State and local governments.

This concludes my statement, sir.

[The prepared statement of Mr. Kammer follows:]

U.S. DEPARTMENT OF COMMERCE
STATEMENT OF RAYMOND G. KAMMER, DEPUTY DIRECTOR
NATIONAL BUREAU OF STANDARDS
BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
ON REAUTHORIZATION OF THE NATIONAL EARTHQUAKE
HAZARDS REDUCTION ACT OF 1977

MARCH 19, 1985

I am here to discuss the earthquake hazard reduction activities of the National Bureau of Standards (NBS). These activities are conducted in the Center for Building Technology (CBT).

Fiscal year 1986 budget

The proposed NBS budget for fiscal year 1986 includes program changes of $33M in a budget of $120M -- $16.4M in increases and $16.5M in decreases. One of the decreases proposed is the termination of the Center for Building Technology. This would include stopping NBS efforts in earthquake hazard reduction. This action is included in the President's budget for two reasons:

- To allow NBS to undertake new programs addressing critical new technologies with greater economic potential to the U.S. without increasing the NBS budget.

- To implement the Administration's policy of disengaging the Federal Government from areas in which State and local governments have primary responsibility. Building and safety codes have traditionally been within the purview of State and local governments.

This concludes my formal statement. I will be pleased to answer any questions you may have.

RAYMOND G. KAMMER

Deputy Director, National Bureau of Standards

Raymond G. Kammer became the Deputy Director of the National Bureau of Standards on September 14, 1980.

NBS is the Nation's central reference laboratory, providing measurement methods, standards, and data that are used in industry, commerce, government, and universities. Bureau headquarters are located in Gaithersburg, Maryland, with a second laboratory at Boulder, Colorado.

As Deputy Director, Mr. Kammer is responsible for the efficient execution of the Bureau's operational programs. He coordinates, monitors, and assesses progress of all NBS technical projects, and of the supporting services.

Mr. Kammer joined NBS in 1969 as a management intern and program analyst. From 1971 to 1974 he served as program and budget analyst at the Department of Commerce. Returning to NBS as senior budget analyst, he subsequently served as senior program analyst, Associate Director for Programs, Budget, and Finance, and Director of Administration and Information Systems.

From April 1983 until September 1983, Mr. Kammer served as Chairman of the Source Evaluation Board for Civil Space Remote Sensing. He was also responsible for developing the Department of Commerce position and program for Space Industries. He is currently representing the Department of Commerce in establishing the Cabinet Council Working Group on Space Commercialization.

Mr. Kammer received a Bachelor of Arts degree from the University of Maryland in 1969.

Mr. WALGREN. I knew we'd be able to finish that. Let's break then, and we will resume in about 15 minutes.

[Recess taken.]

Mr. WALGREN. Well, thank you very much for coming back to order.

Let me ask, Mr. Speck. A rough estimate would be that even though your agency's budget levels are essentially a freeze, that there is some decrease in net effort with the impact of inflation. And one estimate is that it's 15 percent lower than the level recommended by the independent panel that reviewed the 5-year plan, or at least one of the levels discussed by that plan.

Can you indicate what is lost by that kind of a freeze?

Dr. SPECK. Yes, Mr. Chairman and members of the committee, the independent review panel provided two figures. One was at $337.7 million and the other was a B level at $490 million. The 5-year plan proposes a $363 million level, which is over that period of time. Thus the level is somewhere between the two, although it is closer to the lower level than it is to the higher level. Obviously, that means that you would be doing less overall than you would be at the higher level; however, we believe this level still does give you a good comprehensive program.

In terms of cuts for fiscal year 1986 over fiscal year 1985, 1985 was a year of significant increases over fiscal year 1984, particularly for FEMA. The 1986 level however, still represents a substantial increase over the 1984 level. What we have to do there is to stretch some things out. The largest element in that was for moving ahead with a study for a large shake table. That is under consideration as to whether or not we really want to go ahead with that study. The study alone would have required something like $750,000 in our budget at this point, and that is being reviewed by the earthquake policy coordinating committee representing all of the agencies here.

We discussed it at our last meeting, and it is going to be an item on our agenda next, which is the May meeting, with the question about whether we really want to go forward with that, given not merely the cost of the shake table itself but also the very substantial cost in operating, which hadn't been adequately looked at. And that's what we're all looking at together and going to be addressing. The fact that that is going to be drawn out is where most, so far as FEMA's budget is concerned, the cut is absorbed.

Mr. WALGREN. Is that the facility that Dr. Suh raises as a national earthquake experimental test facility where you suggested there were some feasibility studies that you were suggesting?

Dr. SUH. Well, I wasn't particularly referring to the shake table alone, but I think there is a need for the research community to have some large testing facilities of all kinds, and the shake table being one of them. The cost for a shake table, the way it was recommended by NAS, was $200 million, and is going to require considerable study as to whether or not such a shake table ought to be built at this time or should follow very detailed design study. And I think there are many issues we need to resolve.

But in general, the kind of facilities I was talking about, there are other kinds of facilities we need to build which will not cost $200 million but something that we can handle within our means. So these are things we will be discussing.

Mr. WALGREN. But the shake table is so large you could not handle that within your NSF budget without a specific appropriation?

Dr. SUH. If we found that, I think for a couple of years we can all go home and then do something else, because that far exceeds our engineering budget at this time.

Mr. WALGREN. Yes.

All right, now, the difficulty I have is that two people are looking at this, Dr. Speck, for the FEMA people, and apparently some thought being given to it in NSF. How are you coordinating your views?

Dr. SPECK. Mr. Chairman and members of the committee. As I indicated, we took this issue up at some length at the last Earthquake Policy Coordinating Committee, of which each of us is a member. We decided there that we needed further information particularly on the overhead issue—the operating cost side of this—which had not been previously adequately addressed and that we would take it up again at the May meeting. So that there is no one agency here running with this ball. It's something that we're all looking at together because it is, as Dr. Suh indicated, something that is of concern to the scientific community and of concern to all of us. I would expect that it would be a collegial type decision that would come out of the coordinating committee review.

Mr. WALGREN. Is it the National Research Council report that recommends it, is that correct?

Dr. SUH. Yes. The National Academy of Science report. In fact, Dr. Housner, who is a member of the committee, will be testifying later today. So they have made their recommendation.

But what I was referring to earlier is the fact that in addition to that kind of large facility, we need other kinds of facilities as well; for example, we cannot even test large structures on the three-dimensional loading without having a shake table, and to apply steady load cannot be done today because we do not have a national facility of that kind. And so we are considering the possibility of funding one of the universities in establishing such a facility, which may only cost $2 or $3 million.

And even then, it requires fairly significant study, because one of the problems of large-scale facilities of this kind is that we have to make sure that the user community will indeed use it and then benefit the taxpayers afterwards. Sometimes we can build large facilities, and unless we think through the whole entire range of issues involved, we may simply have this facility sit there. And that would not be doing any service to the Nation.

So there are a large number of issues we have to study, and within the National Science Foundation we are taking this up as a major issue, and in fact, we are undertaking a major study as to what our position ought to be vis-a-vis establishment of large testing facilities of several different kinds. And the shake table is one of those, but at this point the cost involved is so large that it is, I think, outside of my immediate purview.

Dr. SPECK. Mr. Chairman, I think it might be interesting, as I recall, the estimated annual operating cost was something in the neighborhood of, $20 million. Now, that happens to be five times FEMA's whole budget for earthquakes on an annual basis. That's

why it's not to say that it isn't needed, it's to say that you need to look at the operating costs as well as the upfront capital costs.

Mr. WALGREN. Are there international facilities that are available to us in this area?

Dr. SUH. Yes. Certainly, in other countries there are facilities of that kind, but if we build this one recommended by the NAS—I believe the table size is 60 feet by 60 feet—this will be the largest in the world. But there are facilities of that kind in other nations. In Japan they have one, and it's smaller. And I understand in the Soviet Union they have one, too, but theirs is slightly smaller.

And our researchers went to Japan to use their facilities, but obviously there are some differences in the way the Japanese view the dangers of earthquake than our researchers do, because the building construction techniques are different. And also, our researchers find that it is somewhat inconvenient to go all the way there to Japan to use their facilities.

However, we are actually looking into all different options, such as a number of nations getting together and building such a large facility because if there is one item that perhaps can be done under international cooperation, this would be it, because every nation has similar problems.

So these are the options we have to investigate and we have to study. But because of the cost involved, I think it's going to take somewhat of a lengthy study to really come up with a coherent plan on the part of the Federal agencies so that we can coordinate it and do a proper job.

Mr. WALGREN. Are the international people within NSF focused on this to the best of your satisfaction?

Dr. SUH. Well, in fact, I stated to our international people that the Engineering Directorate will identify a few critical areas in which we would like to promote international cooperation rather than simply waiting for the university communities to simply come in with a proposal for international cooperation.

We have identified a few areas in which we would like to promote international cooperation, and this would be one of those areas. In fact, I sent, since the NSF is part of this United States-Soviet cooperative agreement, we have been invited to go to Moscow sometime this spring. And I stated to the lead agency's representative that unless the Soviets are willing to really cooperate in certain areas—in this area in this case—in sharing information, then there may not be much point in cooperation.

So as part of our condition for cooperation, we have identified several items for which we would like to get their information. One of these items we asked for is this shake table, how they designed theirs, what kind of results they have obtained, and whether or not we can go and see it. And so far we haven't had any response, because in the past when we had similar agreement with the Soviets, I understand they have gotten a lot more out of us than we got in return. So I don't think we want to repeat that situation all over again.

Mr. WALGREN. Mr. Boehlert.

Mr. BOEHLERT. Yes.

Dr. Speck, you mention here that the various States are in various stages of implementing their earthquake programs. Where are

they? I mean are some really lagging way behind? I would assume, on the west coast, for example, California is probably upfront, and where are we in New York, for example? But where are we in these different areas?

Dr. SPECK. Mr. Chairman, I would say that New York is not quite as far along as some of the other States.

Mr. BOEHLERT. I mean are we far along at all?

Dr. SPECK. Yes. You are making a significant beginning in the sense that I know that FEMA is providing a grant in this fiscal year—I believe it's $65,000—to New York to support planning council activities there. The idea is to begin with the vulnerability assessments, then move ahead in, I believe it is, fiscal year 1987 with preparedness planning and then go on to mitigation in fiscal year 1989. You have an orderly progression of planning underway, but it is really just commencing in New York.

What has happened is that we have looked at the area—and I mean this collectively—and looked at the areas of highest seismic risk. In these areas, some dozen of those areas is where the attention has been primarily focused. California is, for the most part, well ahead of the rest of the Nation. For example, they are further ahead in mitigation because they have had a seismic element built into their building standards for a number of years. This is something that overall is not found in most other areas, although it is commencing to be found in other areas.

We are beginning to see a very active planning movement through a consortium of States in the Central United States, the so-called New Madrid Fault area. On pages 13 through 16 of my prepared testimony, which was considerably expanded over my oral testimony, we have detailed for you the status of activity in each of the 12 major seismic areas. And I would be glad then to expand in any way you would like on that.

Mr. BOEHLERT. Excuse me——

Dr. SPECK. We are moving very substantially with the States, and each of the other agencies can share with you what they are doing with the States, particularly in these areas. We are also, secondly and most importantly, building an integrated emergency management system so that you have the functional framework to deal with all hazards. In essence, you have got to be able to warn people, as well as protect them in place or by moving them, provide emergency services. All of these kinds of basic elements are used in generic planning which FEMA provides civil defense dollars to State and local governments to use.

Finally, we're moving ahead with the Federal response plan in which the agencies here and a number of other agencies are involved, so that where you would have a catastrophic earthquake, the National Government, if it were beyond the capability of State and local governments as it likely would be, would be prepared to come in and meet the needs that were not able to be met by State and local governments.

That response plan is being full field tested with Region 9 of FEMA and the State of California this summer, in early June for the first time. That plan will then be the fourth that's being tested, and out of that we would hope to have a final national re-

sponse plan, which would then be able to be exercised in other high-seismic-risk areas of the country.

Mr. BOEHLERT. It doesn't seem to be any great sense of urgency about it, though. In my previous incarnation I was a county executive in upstate New York, and I can tell you with all confidence that we never heard of earthquake programming or planning.

Dr. SPECK. Well, Mr. Boehlert, that, you know, in part, has been a function of an awakening of the appreciation of the earthquake hazards throughout the United States.

Mr. BOEHLERT. It's a very slow process, isn't it?

Dr. SPECK. Pardon me?

Mr. BOEHLERT. It's a very slow process, because I think we're still asleep in New York.

Dr. SPECK. Well, I don't know that I would want to say that. I think that there is an awakening there, and I think there is a recognition in New York there that overall the hazard is probably considerably less there, from what we know, than from most other areas of the United States. People don't see New York as an area where we are likely to have a catastrophic kind of earthquake.

Now, we're learning more all the time, and I hope that we don't find out that there is a fault in New York where we can expect a catastrophic kind of earthquake. But that I think that that is certainly another factor where you're beginning to see the most activity, is the most evidence of threat of a catastrophic kind or a very major kind of earthquake.

Dr. BOEHLERT. Let me ask Dr. Peck.

Dr. PECK. If I could just interject briefly. We together with FEMA, the Geological Survey held a workshop I think in Albary this last December to pass forward information and heighten the awareness by the State and local leaders of the earthquake hazard. So touch base, maybe.

Mr. BOEHLERT. Let me tell you something—and I don't mean to have this interpreted the wrong way—but I can tell you what county officials do. They probably send their civil defense director off to Albany, and no one really pays attention to the civil defense director. Unfortunately, that's a sad fact of life. So I don't think there is any heightened awareness of the potential for an earthquake in New York, for example, and therefore of the need to develop a plan to respond to the earthquake.

Let me ask another question if I may. I am not certain to whom I should ask it. But you're able to identify the areas of highest seismic risk. Do we have anything like we do with the flood plains where there are restrictions in terms of building in areas of highest seismic risk? If my name were Dow instead of Boehlert, could I build a chemical company in an area of high seismic risk? Is there anything that could stop me?

Dr. PECK. If I may respond to that, in California there is a law that people within a certain distance of active faults have to notify prospective buyers of their property that indeed it is near a prospective fault.

Dr. Filson could perhaps address that more fully.

Dr. FILSON. Yes, sir; in California the Aquas-Priola Act defines special study zones along active faults, and the requirement is there, as I understand it, that sellers have to identify to or notify

prospective buyers that the property is in an active study zone and therefore in the proximity of an active fault, in a special study zone and therefore in the proximity of an active fault.

Mr. BOEHLERT. Realistically, what are we talking about in that? And I suppose they vary in size, but if we're talking about an area of high seismic risk, are we talking about 300 square miles or what? I am trying to get a better feel for it.

Dr. WRIGHT. I am Dick Wright, with the Bureau of Standards. There are large areas of the country with high seismic risk, and this is a chart prepared by the U.S. Geological Survey that shows by the color these areas.

The areas that Dr. Filson was speaking about that are subjected to actual faulting or landsliding are along the seacoasts or the runup of Tsunami. There is very little we can do by careful construction to mitigate those risks. But those are more or less line phenomena, and in those very large areas of the country that you see that are subjected to high shaking there are quite cost-effective things that we can do to anticipate these risks in the design and construction of our structures.

So we do not need to put large areas of the country off limits for useful construction and useful facilities because of seismic risk, we only need to recognize those risks and design, construct, and operate our facilities with reasonable consciousness of those risks.

Mr. BOEHLERT. Dr. Suh, let me ask, why can't we go into an international deal, as we're talking about it with the space station? The West Germans are coming up with $900 million; everybody is beating a path to our door to get into this international venture up in space. Why can't we do something with friend and foe alike, to share the cost so that we can have the type of facility we need and all benefit in like manner from it?

Dr. SUH. Mr. Boehlert, the fact of the matter is that we do have a large number of international cooperations in this field. The United States-Japan cooperative agreement exists. The United States-China agreement exists.

Mr. BOEHLERT. But you indicated with Japan it's a one-way cooperation. We cooperate with the Japanese but they don't cooperate with us.

Dr. SUH. In this area, I think the cooperation with Japan I think is a two-way street. That was meant more with the Soviet Union, going back to the late 1970's.

I feel that this kind of cooperation has taken place. But as far as building a large structure jointly, funded by a large number of nations, is something that we really haven't attempted in the past. So when we talk about building a large shake table, the issues are quite different from the kind of cooperation we had from in the past. And certainly, this is an interesting idea. And after I came down to Washington, I asked a number of people as to whether or not that's an idea that merits some consideration. And at least in my mind, I haven't worked it out yet.

Mr. BOEHLERT. What kind of response did you get when you asked that question?

Dr. SUH. Well, the usual range of positive and negative response you get.

Mr. BOEHLERT. Which means a nonresponse?

[Laughter.]

Dr. SUH. Well, you know, they have valid points. And certainly, we will concede the effectiveness of cost sharing on such a large facility. Especially when it costs $20 million to build and $20 million to maintain, that's a substantial cost.

On the other hand, people do point out the fact that the needs, the research needs are different, the way we build buildings are different from the way Japan, for example, builds theirs. And therefore, they feel that really the national center is really very much in order. And they also point out that in comparison to the scale of economic loss, the $20 million they say is not such a large sum of money.

So you can have a range of opinions on this, and whether or not international cooperation would really enable us to build such a center jointly is something yet to be tried and tested.

Mr. BOEHLERT. Let me ask Dr. Peck a question. On page 15 of your testimony you talk about the 1886 Charleston earthquake, and you said to date we haven't discovered the geologic feature that gave rise to it. We've been studying it since 1886 and we don't have any more now? [Laughter.]

Excuse me for being so very basic, but that's how I think things get accomplished around here.

Dr. PECK. We did a very good study of the earthquake of 1886, one of the first scientific reports on an earthquake and its effects. We have been doing detailed studies in the Charleston area, with some support from the Nuclear Regulatory Commission, over the last few years, and we learned just recently some very important facts about the recurrence of earthquakes in Charleston. We found some evidence that there had been 3 or 4 earthquakes over the last 10,000 or 20,000 years, and before that we did not know that there had been precursors of that Charleston earthquake.

That tends to indicate there is something special in Charleston. The problem is that in the East—and that means east of the Rocky Mountains—the earthquakes occur along faults that typically are buried by many feet, many thousands of feet, of sediment. So they're not exposed the way the San Andreas Fault is in California. As a result, it's difficult.

You have to determine by indirection, by geophysical means, just what those faults are, and sometimes with an earthquake that happened 100 years ago, it's difficult to locate it precisely on one of those structures that you determined geophysically.

And as yet, to my knowledge—and Dr. Filson can elaborate—we haven't identified that particular—we've identified a number of structures at depths beneath Charleston, but we're not sure exactly on which one that earthquake occurred.

Mr. BOEHLERT. Mr. Kammer, I assume that your work is important work. Who is going to do it when you no longer do it if we don't give you the money to do it with?

Mr. KAMMER. Well——

Mr. BOEHLERT. I mean is it realistic to assume the private sector is going to assume that responsibility?

Mr. KAMMER. There has been some activity in the private sector to this end. There is an entity called the Building Seismic Safety Council, which, with support from FEMA and the National Bureau

of Standards, has devised a draft set of provisions which would be, in effect, guidance to private sector builders that would allow them to build more earthquake-resistant structures.

They are in the process of reviewing that draft now and getting a lot of comments on it. That is one possibility. There is something in being.

Mr. WALGREN. Would the gentleman yield?

Mr. BOEHLERT. Sure.

Mr. WALGREN. What did they base their recommendations on?

Mr. KAMMER. Well, to a great extent on technical advice that they got from the Bureau of Standards.

Mr. WALGREN. And they got that information that underlies their recommendations from the Center for Building Technology.

Mr. KAMMER. Yes, sir.

Mr. WALGREN. And so if the Center for Building Technology did not exist, there would not exist the information base for this private sector group to develop its standards.

Mr. KAMMER. Well, there is a lot of activity in universities as well, sir; a lot funded by NSF, for instance. And it's not easy to imagine that it would be pulled together in one place at the start, but I think with some effort people could get the information.

Mr. WALGREN. I thank the gentleman.

Mr. BOEHLERT. Would you say that you share Mr. Stockman's enthusiasm for elimination of the center? Is that a fair question? Do you want to slip the answer under the table here? [Laughter.]

No; I don't think it's fair to ask you the question. You dealt with it, and we're going to see to it that things are a little bit different.

Thank you all very much.

Mr. WALGREN. Thank you, Mr. Boehlert.

Let me go back to Dr. Speck and ask again about the annual report that you suggest be eliminated that the Congress apparently requires.

You have indicated that there are two annual reports, one that is required by the act and the other that apparently comes each year, with what? Would you describe those, the differences between those reports?

Dr. SPECK. Yes, Mr. Chairman. The difference is that one is an annual report on what has been accomplished under the National Earthquake Hazards Reduction Program in the preceding year. That's the annual report of what's been done.

The second, which we feel it is not really effective to redo every year, is the annual update of the 5-year plan. And the act requires that there be an annual update of the 5-year plan. What we had asked for and recommended legislation was that the plan be updated when there were significant changes in terms of agency programs or, at a minimum, every 5 years. In other words, it would be updated automatically every 5 years or whenever there was a significant change, because the programs tend to be multiyear and you're getting an annual report on what's been accomplished under the program on an annual basis.

Mr. WALGREN. Would you comment on that? Is there some view of that, the usefulness of this process, that you could give to us, Dr. Peck?

Dr. PECK. Well, quite frankly, in our area, the Geological Survey, I think the progress is such that updating and modifying the plan more often would be desirable, and that, as a minimum, at least every 2 years, perhaps in sync with the authorization hearings, would be an appropriate intermediate position.

Mr. WALGREN. How is it desirable to update that plan? What is it about the process of updating a plan that you feel is useful?

Dr. PECK. Well, as you learn more about the phenomena—our ideas, for example, have changed considerably over the last several years; in fact, since the first drafts were submitted for that plan about how to approach the problem of predicting earthquakes, and now we're focusing in areas where just over the past few years we've learned to identify a high probability of a substantial earthquake in the future, like at Parkfield. And I think it's important for every agency to go through that rethinking and to communicate its rethinking to its sister agencies in the program.

Mr. WALGREN. Yes; I see.

Other comments on the usefulness of this process of rethinking the plan, Dr. Suh?

Dr. SUH. Well, Mr. Chairman, we have been spending a great deal of effort trying to really examine whether or not we are doing the right thing in terms of the kind of research we should support, the kind of problems we address, and the kind of technology transfer mechanisms we employ to make sure that our research results are used.

So in that sense we are making many changes, and do intend to inform the Congress every time we make these changes. However, because of the changes we are making are within this very broad outline of the plan, the changes we have made so far really does not affect the 5-year plan to any significant degree that I know of.

And so my feeling is purely the updating the 5-year plan is good, whether it should be 1 year or 2 years, I think everyone would have some different opinion. But the point that I am making is that we are making many changes, we are asking some tough questions, but I think all of these lie within the 5-year plan that has been established.

Mr. WALGREN. Dr. Speck, your thought is that, in fact, when you do make a revision, you would be communicating that revision to the Congress, is that right?

Dr. SPECK. Yes. The proposal is one that you would have an update at least every 5 years, but whenever there were significant changes you would also have an update. I would expect that to be a decision of the Policy Coordinating Committee, a collegial decision of the agencies that are a part of that body, that is, the agencies here.

Mr. WALGREN. Well, we don't want to be overly procedural, and we will certainly try to give that some thought.

Dr. Peck, the thought of a prototype prediction network in California has been of interest to the committee, and as I understand it, last year a survey of feasibility studies were conducted on deployment of a prototype network. Where are we on an actual—and I gather that would be the use of the word "prototype"—an actual in-place network in southern California that would allow us to predict?

Dr. PECK. Yes; Dr. Filson and his staff prepared sort of an option plan, looking at a number of different ways to approach this prediction problem. And they have reviewed that extensively with the California Earthquake Prediction Council, our own advisory committee, with the State geologist and his staff. And he would be the best informed to talk about the matter.

Mr. WALGREN. Well, maybe you could give us a brief outline.

Dr. FILSON. Yes, sir. Mr. Chairman, the basic concept that evolved out of the various studies we've done on prototype networks, prototype prediction networks, used as their unit building block an earthquake prediction instrument cluster, if you will. A cluster would consist of several instruments focused in a particular area where we understood the mechanics of the fault or thought we understood the mechanics of the fault and we knew what earthquake it was we were trying to predict.

The option paper, the strategy paper or option paper that we laid out, consisted of four basic options. One was to proceed with our current research program. Other options, the second option included deployment of a cluster of this instrumentation at Parkfield, CA, where we think there is a high probability of an earthquake in the next few years, and a few other sites along the San Andreas Fault in southern California.

Option three, we identified—or considered the deployment of 20 to 30 clusters in southern California; and option four, 40 to 60 clusters of instruments throughout the State from San Francisco south to the Mexican border.

We have reviewed this paper with committees of the National Research Council and the California Seismic Safety Commission and our own several other groups. And the consensus seemed to be that it was premature to proceed with options three and four, the wide deployment of prototype or prediction clusters throughout the State, but that all the groups endorsed our efforts at Parkfield, CA, which are identified on this map. I won't go through the details of the chart, but each instrument—or each symbol represents a different type of instrument that would be used for earthquake prediction purposes.

So the short answer to your question is that the prototype—an example of a prototype prediction cluster is in place at Parkfield, CA. The issue of what additional clusters are needed has been reviewed in several bodies. And the consensus seems to be that we should talk about deploying additional clusters, a few additional clusters in those parts of the State along those places along the fault where we think there is a high probability of an event in the next few years.

Dr. PECK. If I could add, sir, one fact that leads us to focus our efforts at Parkfield is that there has been a magnitude 6 earthquake every 22 years for the last 100 years. And those 22 years are up in 1988. The last one was June 1966. So there is really a high probability that there will be a magnitude 6 earthquake in this area——

Mr. BOEHLERT. Excuse me, Doctor. Isn't that an average? I looked at those figures, and it said every 22 years. But that's an average. It could be 21 or 20.

Dr. PECK. Yes, yes.

Mr. BOEHLERT. If I get nervous, I am going to write my stepmother out there and tell her. [Laughter.]

Dr. PECK. But there certainly is a high probability. Few stepmothers live in this area, actually [laughter] because Parkfield has a population of 30 and it's arid ranchland.

Mr. WALGREN. Is one of those Secretary Clark?

Dr. PECK. One of those is Secretary Clark. I don't think he's anybody's mother-in-law, but [laughter] but their ranch is just 7 miles from Parkfield, and he was very interested in our experiment. Certainly, there is a high likelihood that there will be an earthquake there within the next 5 years. And so by really focusing our efforts there, this would seem to increase the chances of actually seeing some phenomena occur before the earthquake that we could use for prediction purposes. And that's the reason for it.

Mr. WALGREN. OK.

Dr. Suh, you indicate that there is a lot of fundamental research to be done on the engineering of building structures and their relationships to earthquakes and the like. Would that not be a strong argument for continuing the Center for Building Technology?

Dr. SUH. Mr. Chairman, frankly I really don't know much about the National Bureau of Standards, so I am not in a really good position to say exactly what they have been doing and how it interacts with our university research community. And so I would be willing to study the subject matter and then submit a written response to you.

Mr. WALGREN. OK. Well, gentlemen, thank you very much for your testimony. We appreciate your contribution to the record, and we will be getting back to you. Thank you.

The second panel is made up of Dr. George Housner, the professor emeritus of earthquake engineering at California Institute of Technology; Dr. Mihran Agababian, chairman of the civil engineering department of the University of Southern California; Dr. Richard Olson, professor of public affairs at Arizona State University; Dr. John Wiggins, president of J.H. Wiggins Co., who is in association with Stanford University; and Dr. Jack Oliver, the director of the Institute for the Study of the Continents at Cornell University.

I would like to start, and if you gentlemen would come forward, let me ask if Dr. Oliver would be our leadoff witness and then we will return to the order in which you were introduced.

Again, written statements will be made part of the record without more. And please feel free to summarize and underline the thoughts that you feel are most important to emphasize.

If you would, proceed, Dr. Oliver, in whatever way you feel best. Thank you.

STATEMENT OF DR. JACK E. OLIVER, DIRECTOR, INSTITUTE FOR THE STUDY OF THE CONTINENTS, AND PROFESSOR, DEPARTMENT OF GEOLOGICAL SCIENCES, CORNELL UNIVERSITY

Dr. OLIVER. My topic is research on the continental lithosphere, and I have given you a written presentation that covers that subject. It provides a certain historical perspective to the activities that are going on in this discipline now, and it provides some other information on matters that include the interaction between the

continental lithosphere and other parts of the Earth. That's in my written testimony.

I would like to focus in my oral testimony on one particular part of that subject, and that is the study of continental tectonics. I am referring now to the continental crust that is the upper 40 kilometers or so of the Earth, and that's the upper 40 kilometers or so of the 150-kilometer-thick lithosphere.

Continental tectonics is a subject that is in a very exciting stage right now. We're in the phase of major discovery in this branch of science. We're exploring the interior of the continents for the first time by methods which are providing a new kind of data and enabling us to develop this subject at the present time.

Furthermore, I am sure in general you are familiar with the theory of plate tectonics which was developed in the 1960's and which was probably the greatest advance ever in the history of geology.

Now, when that theory was developed, the continents were included, of course. The oceans opened and spread and the continents drifted and collided. But in those early stages there was no deformation of the continents, that is, the interiors of the continents. Now the subject is evolving in such a way that we're explaining the deformation of the continents which is so obvious to all field geologists.

Now, let me start my study first in the Western United States. Could we have the first slide, please.

[Slide.]

Dr. OLIVER. This is the story of the accreted terranes in the West. Those things that you see in the uncolored area in the western North America are the accreted terranes. Those terranes are something like the froth on a pot of soup. You've heard the analogy, I am sure, of convection in a pot of soup in which little flecks of froth drift over to the side and are accumulated. Well, that's the role of the terranes and the continents. The continents are formed of these little flecks which have been carried across the ocean and added to the continent in this manner.

In the Western United States, at least in the early stages, the evidence was all from surface geology and from the study of paleomagnetism of the rocks. At that stage we had no information on the deep structure of the continents. We're beginning to get some now.

But now I would like to switch to the Eastern United States, where we do have some evidence on the interior structure of the continents. I am going to talk about the Appalachians, the feature you see running away from the south on up into Canada and beyond. And particularly, I am going to show you some evidence from that line running down through Georgia, the dark line running from northwest to southeast. That's a line where a seismic reflection profile was made in the late 1970's, by COCORP, the Consortium for Continental Reflection Profiling, which is in a way a nationwide consortium but it's centered at my university, Cornell, and so that's why I will present this. I have access to this kind of data to give it to you.

The thing that this profile shows—next slide, please.

[Slide.]

Dr. OLIVER. It shows that the structure of the eastern part of the continent was something like this. That's a block diagram now with a section on the side facing you, and to the right you can see the modern Atlantic Ocean. To the left of that you see the coast, the coastal plain, and then the rocks of the Piedmont, the Blue Ridge, and eventually the Appalachian Plateau.

The story that emerged from this early survey was that the rocks of the Blue Ridge and the Piedmont and the coastal plain had been thrust up on to a preexisting continental margin. You see to the right the modern continental margin and below that to the left you can see an equivalent continental margin of much older age.

And that happened in this fashion. At the present we have the modern Atlantic Ocean, and it's spreading apart. Africa is retreating from North America. However, before the Atlantic Ocean existed, the two continents of Africa and North America were together.

Before that, there was an earlier version of the Atlantic Ocean, which scientists called Iapetus. As Iapetus opened initially, it made the continental margin that you now see buried to the left. And then as the Iapetus ocean closed, fragments of the sea floor, sea mounts, island arcs, sediments, all sorts of debris were scraped off the ocean and pushed up into the continent in the form of that thin sheet that you see sliding up there.

When this happened, there must have been huge earthquakes, earthquakes like the one in Alaska in 1964. But the process has left zones of weakness and it has probably left a modest rate of deformation which is associated with the earthquakes that we have today.

The process of sliding a thin sheet on the continent also did some other very spectacular things. For one thing, it buried some sediments down there—the thin gray layer with the arrow above it to the left of the slide. Those sediments now are probably highly metamorphosed, but some of them may not be, and if they're not, then they are possible places to look for petroleum.

Furthermore, as the thin sheet slid onto the continent, it loaded the continent down with this weight, so it created a great sedimentary trough, the Appalachian trough, which was filled in with the sediments. And those sediments are the source of some of our petroleum.

In addition, when Africa finally came over and collided with that thin sheet, it pushed itself further on the continent and wrinkled up the sediments ahead of it like a scuffed carpet on the floor, and it produced the spectacular folded mountains that you see in Pennsylvania, for example.

Furthermore, in this process of loading, the thin sheet was thrust onto sediments of the preexisting margin that were wet. They were full of seawater, brines, dissolved minerals, perhaps even petroleum in a beginning form. When that sheet was pushed onto the sediments, it squeezed the fluids out and perhaps drove them for huge distances into the interior of the continent, perhaps hundreds of miles, so that some of our mineral deposits in the interior of the continent and some of our petroleum deposits in places like Ohio, for example, or western Pennsylvania, some of that petroleum may have migrated from this collision zone for those large distances, eventually to be trapped in the places where we find it now.

Now can we move to the next slide, please.

[Slide.]

Dr. OLIVER. Now I will tell you a little bit more about some of the things that have been developing recently. The black line there in the upper part of the slide, running through Georgia, was the first COCORP line that I described. The heavier dark red lines are a more recent COCORP survey, running from Georgia down into Florida. And the reason we were on this line here is that we wanted to cross what's called the suture zone.

You see, Florida and a part of Georgia are really a part of Africa which was left behind when the Atlantic Ocean began to split apart. They had come over with Africa when the Iapetus closed, and they were left behind when Africa retreated.

Now, what we were looking for was to see if we could see the scar of this old joining of Africa and North America. And so we ran seismic lines along those red lines that you see there.

Dr. OLIVER. And if I could have the next slide, please.

[Slide.]

Dr. OLIVER. Well, you can't see this very well, but just look at the top part of the section. That's a line drawing of the actual seismic data. Below in color you see a geological interpretation. If you look at the upper one, for example, you will see—you're seeing a section through the entire crust. That lower set of dashes is the base of the crust at a depth of about 40 kilometers.

And the upper things in most of the sections, the upper dark lines in most of the sections, are the sediments. They're the sediments of Cenozoic Age and Mesozoic Age and Paleozoic Age.

But over at the right, if you look under where it says "GA-13" and "GA-14," you'll see that something entirely different is happening in the interior of the crust. It starts right up at the base of the sediments; it runs right down to the base of the crust. It occupies a zone about 60 kilometers in width. That is the suture zone. That is the scar of the collision of Africa and North America as Iapetus closed.

Now I would like to show you something special which has just come out of our computer in about the last 10 days and which I think is an important new observation on the crust in this suture zone.

The next slide, please.

[Slide.]

Dr. OLIVER. This is a set of real seismic data. It's been processed in our computer in such a way that the only features you can see are horizons which reflect the seismic energy extremely well. Up near the very top of the slide, just under the place where it says "COCORP," you see a dark zone. Those are nicely layered sedimentary rocks of very recent age. And they make rather nice reflectors, so we see quite a bit of energy coming from that part of the Earth. That's where the petroleum industry would look for all its petroleum.

Now, immediately in the center of the slide you see an extremely bright reflector. It's almost a mirror-like reflector in the interior of the crust. It is, I think, the brightest reflector that the COCORP project has ever observed in the crust.

The next slide, please.

[Slide.]

Dr. OLIVER. This is taken from a textbook. This is the kind of feature which the petroleum industry seeks in petroliferous areas, and when it finds one like this, it's a feature of very high amplitude—and you notice it's very flat across the top—it's called a "bright spot," and they drill nearly all these bright spots because most of them are associated with gas or sometimes oil and sometimes brines as well.

The next slide——

[Slide.]

Dr. OLIVER [continuing]. Shows a detailed version of the COCORP bright spot that I showed you earlier. You notice it looks almost identical to the one which was in the textbook as a place where petroleum occurred. Now, the difference is that the COCORP bright spot is at a depth of approximately 55,000 feet, which is about twice the depth of the deepest hole that's ever been drilled for oil. So nobody is going to go out here tomorrow and drill this and hope to produce petroleum. However, it's a very interesting phenomenon because it's telling us something about fluids in the deep interior of the crust.

Now, the role of fluids in the rocks of the crust is critical in the story of tectonics and how the rocks deform. It determines the rheology of the crust, it determines the geochemistry of the crust, and, among other things, it may have a strong role in the earthquake phenomenon because fluids under pressure have a kind of a lubricating effect on a fault and may be a very critical thing.

So here is a very recent observation which should give you some idea of the kinds of things which we are now capable of observing on the interior of the crust.

The next slide, please.

[Slide.]

Dr. OLIVER. Well, this is a map, a tectonic map, of all of North America. I showed you the Appalachians. I referred to the features on the western part of North America. If you look, in Canada you can see several other bands, one running up to the northeast and some running to the northwest. These are probably earlier versions of this same process of ocean opening and closing.

My point with this slide is to show you that we're discovering something fundamental about the way the continents have been formed and how they've evolved through geologic time.

The next slide, please.

[Slide.]

Dr. OLIVER. Here's a different kind of a phenomenon. I have been talking about places where continents converge. Now I am going to tell you briefly about places where they're pulled apart. That gray band beginning down in Kansas and running up through Nebraska, Iowa, Minnesota, Wisconsin, and running down into Michigan is a gravity anomaly. It's an indication that something peculiar is happening to the crust, and it's thought to be a place where the crust has been pulled apart.

The next slide shows a seismic section in Kansas

[Slide.]

Dr. OLIVER. And there is an awful lot of information here. And I only draw to your attention the one feature which is up there just

below and to the right of the figure "2000" on the left hand part of the side. It goes down from about zero to five on that vertical coordinate of time.

That feature is the first detail that anyone has found on this kind of a rift structure in the interior of the continent. It is interpreted as being due to the result of sediments which were deposited in a place where a great block of crust dropped down as the continent was pulled apart.

This is not the kind of feature which would be prospected by the oil companies, because the rocks are too old. They're about a billion years old and would not be thought to be petroliferous. However, once we found this feature, at least as the press reports it, Texaco has now drilled a hole about 4 miles north of this line in Kansas. The results of that drilling have not been made public by Texaco, and of course we hope they found a big oilfield or somebody finds a big oil field on the basis of this.

But it demonstrates how little we know about the deep part of the crust, and how by taking a fundamental look at what is down in the crust, just trying to learn this basic information, our society may be able to make some major advances in the way it uses this part of the Earth.

Next slide, please.

[Slide.]

Dr. OLIVER. Well, this slide is not a very good one, I see, at this scale. But this is across the Basin and Range province of California, Nevada, and Utah. And it shows some very fundamental things about the way in which the crust is being pulled apart to make the spectacular topographic features that we see on the surface now in the Basin Range.

Also, at the left of the slide over there under where it says "Sierra Nevada" and "California," there are some faults, one of which seems to be associated with the great Mother Lode gold deposit in California and may very well be an indication of the plumbing system which brought that great mineral deposit to the surface.

There are some other little faults over there that are associated with the surface features from which geologists can determine that they have moved in fairly recent time. So this is an indication of the way in which this kind of data tells us about faults which may very well be earthquake related and how they penetrate into the deep part of the crust.

Next slide, please.

[Slide.]

Dr. OLIVER. Well, this is one for New York. This shows another kind of data. It's taken in the beautiful Adirondack Mountains of New York, just below the great Mount Marcy, an anorthosite body, up there. And what it shows is about two-thirds——

Mr. BOEHLERT. I recognized it instantly. [Laughter.]

Dr. OLIVER. You did? [Laughter.]

What it shows here down at about a depth of about 20 kilometers—that's about two-thirds of the way down the slide; 20 kilometers is about 12 miles—is a very mysterious feature. It's a zone of layered rocks which have no business being under these highly deformed crystalline rocks of the Adirondacks.

It's a kind of a mystery feature. We don't know what it is now. We don't know how those layers got there, but we think that eventually when we're able to trace them with more profiles, we'll be able to follow them to the surface or eventually from their configuration, identify them, and so learn about the crust in this part of New York.

Just one or two more slides.

Next slide, please.

[Slide.]

Dr. OLIVER. This slide shows the history of COCORP reflection profiling. The upper left map of the United States there shows a couple of little dots. That's what was completed through 1975. The lower right one that's not filled in so much shows the amount of surveying that's been done to date. It's about 6,000 kilometers. The project has been going for about 10 years. At the moment we operate at the level of one seismic crew going year round in the field.

The technique, incidentally, is that developed by the petroleum industry for exploration for oil, modified somewhat so that we're able to look much more deeply into the Earth and look for these more fundamental features.

Down at the bottom is one of our dreams. You see it's "2020." With our present accomplishments, it's clear that we have done only a tiny fraction of what we could.

Imagine that you were coming to North America, you were the first person to come to North America just to see the surface, and you only covered the routes that COCORP has covered with the seismic lines. You'd have a very difficult time trying to determine what the continent was like. That's the situation we're in with our surveys of the deep interior now. So our society must look forward at some time to having a dense network of seismic lines, something like the one in the lower figure, which will tell us what's down there and how we can use that part of the Earth to our advantage.

Next slide, please, and last one.

[Slide.]

Dr. OLIVER. The next slide shows the global plan of a similar kind of thing. We published this about 1981, and now there are about a dozen countries which have joined in this effort to complete this kind of survey of the crust. When we get this, I will guarantee you that our understanding of the continents will be different and our understanding of earthquakes will be improved.

Thank you very much.

[The prepared statement of Dr. Oliver follows:]

* Testimony before Subcommittee on Science, Research and Technology, Committee on Science and Technology, U. S. House of Representatives, 19 March 1985 by Jack Oliver, Director of the Institute for the Study of the Continents (INSTOC) and Church Professor of Geological Sciences, Cornell University, Ithaca, NY 14853

Continental Tectonics and the Continental Lithosphere

This presentation is about scientific research on the continental lithosphere, and particularly on the continental crust, the upper 40 km or so of the normally 100 or so km-thick lithosphere. This part of the earth is a great frontier of modern earth science. The subject is in its major discovery phase at the present time. We are making surprising, frequently astonishing, new observations about the continental crust, and we are developing a new and striking concept of continental tectonics to supplement and be a part of the concept of plate tectonics that revolutionized earth science in the 1960's but that dwelt largely with oceanic phenomena.

Understanding continental tectonics is important from a purely intellectual standpoint, but it is also a matter of great practical importance as well. Billions of humans live on the earth's continents and derive their livelihood from them. Our ever-growing and ever more demanding society needs to understand thoroughly how to use wisely our mineral and energy and hydrological resources, and how we can use the earth to our benefit in other ways, waste storage for example. Of special relevance to this Committee is the need to know how and why and where and when rupturing of the continents will occur and cause destructive earthquakes like the San Francisco earthquake of 1906, the New Madrid earthquakes of 1811-12, the Charleston earthquakes of 1886, or the catastrophic earthquakes that have occurred sporadically over many centuries in China. To know continental tectonics is the basic step.

In addition to the immediate scientific opportunities and the potential for practical benefit, the prime position of the continents in modern science is also evident from a broad historical perspective. The earth has

been spinning its way through space for some four and a half billion years, and humans have occupied it for a few million of those years, yet it is only in the last few hundred years that we have learned what the entire surface of the earth looks like! We happen to be alive during that brief moment of earth history when, for the first time, earth organisms are obtaining a comprehensive knowledge of their planet. The first phase, geographical exploration of the surface, is already virtually complete although only recently so. There are no more major discoveries, no new continents, no new seas to find. The effects of geographical exploration on our society have been profound, both intellectually and practically. Our views of ourselves, our capabilities, and our future have changed. Our civilization has expanded to new continents, grown in numbers, and exploded technologically.

The technological explosion is also dependent on another phase of earth exploration, one that closely followed geographical exploration. That is the geological exploration of the earth's surface. Although a great deal of detailed mapping and study remains to be done in most parts of the world, in a gross reconnaissance sense, surface rocks almost everywhere have been seen by geologists and the early phase of geological exploration of the surface is also complete. Widespread and growing use of earth resources is an important consequence of this effort.

About a century ago, the attention of earth explorers began to focus on the earth's interior. Study of rocks transported to the surface from depths, and investigations of earthquakes, gravity, magnetism, and other earth phenomena have produced a useful but blurred conception of the deep interior. Our current fuzzy picture is intriguing, but it calls out for more detailed studies. Such studies will be important because they reveal phenomena of the deep interior, such as convective motion, that produce consequences that we observe as geological features in the rocks of the surface. The proposed global digital seismograph network, which will provide information on the deep interior; the proposed 1000-station portable array, which is especially effective at intermediate-depth ranges; and a variety of other proposed geological, geochemical, and geophysical studies are designed to probe this deep frontier, and will provide information to facilitate the understanding of the continental lithosphere and its

interaction with the deeper interior. Other techniques such as drilling and seismic reflection profiling will provide important information on the buried continental crust.

So far most of the buried continental crust is unexplored or explored only by methods of low resolution. Only one subdivision of the continental crust has been and is being explored in considerable detail. That subdivision comprises the sedimentary basins, the locale of petroleum. For the last 100 years the search for petroleum by industry has brought ever-increasing skill and intensity to study of the sedimentary basins. A huge effort has been mounted. Although much work remains, one can sense that the subject is in the process of being mastered. Basins throughout the world are being mapped, classified, and understood in increasing detail. This major effort in earth exploration by the petroleum industry has drastically modified our society. Though driven by the economic incentive, it has also brought us great depth of understanding of this one part of the earth's interior. Furthermore, in the process of exploring these relatively shallow basins, industry has developed tools and techniques that can be readily applied, as we shall see later, to study of the remaining portions of the continental crust.

To place the exploration of the continental crust in further perspective, consider the investigation of the only other part of the earth's interior that has been explored in detail. That part is made up of the ocean basins. The speed and the consequences of this phase of earth exploration have been remarkable. In the two decades that followed WW II, a substantial effort to explore the ocean basins in detail began, grew, and thrived. By the late 1960's, as a result of this effort, the field of earth science had been transformed. The concept of plate tectonics was discovered, providing for the first time a global framework in which to relate observations throughout the earth. A volcano in Iceland, for example, suddenly became closely related to some sediments in Indonesia. This major scientific achievement, perhaps the greatest advance ever in geology, is still being developed and the full practical consequences are yet to be felt.

The next major targets in the history of exploration of the earth are

clearly the interiors of the continents. The petroleum industry has produced two tools of major importance for study of the continental interiors, not only for the sedimentary basins but everywhere. One is drilling. This method is expensive, and it samples only a tiny fraction of the object of study, but if we are to explore the earth beneath our feet thoroughly, we must have in our hands and in our labs representative pieces of the portions of the continents available to us. And we must measure certain phenomena of the interior. For these reasons the U.S., and other countries, are developing programs for deep scientific drilling. Such programs are certain to provide astonishing new information on the earth's interior simply because exploration of the unknown always produces surprises. The programs will also provide means of testing geological hypotheses. It is essential that society make this effort to understand its surroundings. Because of the great expense drilling will always be limited, and sites for drilling must be wisely selected. The crust must be explored as thoroughly as practicable by other methods in order to provide as advanced scientific knowledge as possble prior to undertaking drilling, and to provide the means for extrapolating drill hole information to other parts of the crust.

The second technique developed by the petroleum industry and applicable to study of the continental basement is seismic reflection profiling. This technique has the greatest potential of all for revealing information on geological character on the deep buried crust. Modern drilling rigs are capable of penetrating to 12 or 15 km; seismic reflection profiling with modern equipment commonly penetrates to the very base of the crust at 40 or so km. The latter technique produces cross sections of the earth that represent some of the major geological features over sections many hundred kilometers in length.

Now I would like to tell you about continental tectonics, why that subject is so exciting at present, why it is important and how it relates to the earthquake problem.

During the 1960's earth scientists discovered the concept of plate tectonics, perhaps the greatest advance ever in study of the earth. In plate tectonics, oceans open and close, sea floor is created and destroyed,

and continents drift and collide. Most major earthquakes are associated with interactions of the great plates of lithosphere that cover the earth's surface in a giant mosaic.

In this powerful but simple first model, emphasis is on the ocean basins; continents are relatively passive and rigid entities. This simplified characterization of the continents belies the deformation and change that is evident to the field geologist observing the land surface. Therefore, working from the basic global tectonic theory, we must develop a more complex supplementary model of continental tectonics that will tell us how the continents have formed and evolved, how mineral and energy resources have been concentrated, how the infrequent but especially destructive intracontinental earthquakes take place, and how other phenomena such as volcanism and fluid migration can be explained.

Our study of continental tectonics is at an early stage, but it is developing and evolving rapidly.

One part of the story has to do with the accreted terranes (Figure 1). In the western and the eastern United States, and in Alaska, and in other parts of the world such as China, evidence from surface geology and from the paleomagnetism of surface rocks indicates that parts of the continents have been added piece by piece to a nucleus, eventually to form the continents we see today. These additions consist of island arcs, plateaus, sea mounts, sediments, and continental fragments, one might say debris of the sea floor, that has been added to the continent as the sea floor disappeared into the interior. You may recall the analogy between convection in the earth and in a pot of soup. In this analogy the continents correspond to the scum at the side of the pot, being added to bit by bit as convection proceeds. This simple picture is intriguing, but it fails to give us much detail about how the phenomenon occurs on the scale of geological observatons.

Another kind of evidence is becoming available on the interior as a result of seismic reflection profiling of the continental interior. The industry-developed technique is modified slightly to probe the entire continental crust. This work has been underway for about 10 years through the COCORP (Consortium for Continental Reflection Profiling) project based

at Cornell University where I am employed. Many scientists from government, industry, and other universities participate. Some surveys have also been carried out by the USGS and other universities.

For a scientist, working for COCORP is exciting, simply because COCORP frequently produces what every researcher seeks, i.e., major new discoveries. Almost every COCORP survey has produced information on the crust of the earth that is unexpected, sometimes astonishing, and that challenges the ingenuity of the scientist to interpret and understand these new observations.

In 1978, COCORP began what has turned out to be a series of revealing studies in the southern Appalachians (Figures 2, 3, 4, and 5). In fact, the COCORP crew is surveying in Georgia at the time of this writing. The story that is evolving based on the seismic data and other geological information is fascinating. It is a consequence of the opening and closing of an ancient ocean, Iapetus, that existed at the site of the present Atlantic hundreds of millions of years ago, and also of the subsequent opening of the modern Atlantic Ocean.

When Iapetus existed a few hundred million years ago, its margins and its floor were covered with sediments, with volcanic islands, and with other ocean features such as sea mounts, plateaus, and small continental fragments. As that ocean closed and the continent to the east, loosely speaking what is now Africa, approached North America, the material of the sea floor was caught up in the collisional process and some of it was forced onto the edges of the colliding continents in the form of thin sheets of metamorphic and igneous rock. These sheets, segmented and perhaps only 10 or 20 km thick, were sometimes slid onto the continent over distances as great as several hundred kilometers. The famous Blue Ridge, and the Piedmont rocks on which the nation's capitol is built are part of one such thin sheet. These rocks pushed continental rocks ahead of them, sometimes wrinkling them like a scuffed carpet to form features such as the spectacular folded mountains of Pennsylvania. When the huge collision was taking place, there must have been frequent earthquakes in the eastern U.S. comparable to the largest earthquakes ever felt in Alaska, Chile, or the Himalayas. Now that the collision is over, our challenge is to learn how

its scars and its aftereffects localize and perhaps cause the more moderate but still hazardous eathquakes of today.

The thin sheet of rocks now overlies the old continental margin of Iapetus. The sedimentary rocks of the old margin are of some interest in petroleum exploration, for if in places they have not been highly metamorphosed, they may be considered as targets for future exploration, or they may include the source rocks of petroleum now found elsewhere.

Some continental rocks ahead of the great thrust sheets are deformed and become part of it, and are important producers of petroleum not only in the Appalachians but also in places such as the western overthrust belt and the Ouachitas in the south. COCORP studies in New England and New York, in Arkansas, in Wyoming, in Utah, in Nevada, and rather recently in Washington are designed to probe the basic mechanics and history of this major tectonic process and so provide an understanding of this phenomenon that produces substantial benefits for our society, as well as leaving a fractured and deformed crust that is the host for modern earthquakes.

The current COCORP survey in Georgia seems to be providing spectacular results. It has revealed, for the first time, a detailed seismic picture of what geologists call the suture zone, that is, the place where the two colliding continents, North America and Africa, met and were welded together. It was possible to find such a zone in Georgia because as Africa retreated to form the modern Atlantic, it left behind a small fragment that now makes up Florida and a part of Georgia, and the weld, or suture, that is the connection.

At this preliminary stage of investigation it is already clear that the features of the suture zone are impressive. the zone extends through the entire crust, i.e., to depths of 35 km and is 50 to 200 km across (Figure 5).

When the thin sheets of rocks are thrust upon the continent they load it down with their weight and cause a part of the continent to subside. Huge troughs are formed beneath and inland of the thrust sheet. The troughs accumulate sediments, some of which will become the sources, others the reservoirs of petroleum. Sediments beneath the thrust sheet may be

metamorphosed; igneous intrusions may accompany the thrusting and further add to and modify the continent.

When the rocks of the thrust sheet bury the thick wet sediments of the preexisting continental margins, fluids in these sediments are expelled. The fluids may be mineral-laden brines and they may include petroleum that has been formed through decay of the organic material in the sediments. One reasonable hypothesis has it that the fluids are driven by the loading or by other means for large horizontal distances, perhaps many hundreds of km, through permeable beds into the interior of the continents. Petroleum and minerals may be carried along, eventually to be trapped or deposited. Thus some of our modern oil fields may have petroleum that has migrated over long distances from its source rock in the orogenic belts. Mineral deposits now in the mid-continent may have been transported from the orogenic belt in brines driven by continental tectonics. Some of the modern movements of the earth, and that includes modern earthquakes, may be the result of long-term response of highly viscous earth materials to the orogenic process. Earthquakes in Alaska today are the immediate response of the earth to modern orogeny. Earthquakes of the eastern U.S. may be the readjustment to orogenic forces active millions of years before. And these earthquakes are likely associated with weaknesses of the crust that also date from that distant past. Scientists have begun to model these processes using high-speed computers. As such modeling proceeds and as computers develop, one can anticipate an understanding of the entire orogenic phenomenon that will far surpass what we have today.

A partially completed COCORP survey in the State of Washington will ultimately cross the entire Cordillera of the western U.S. and explore the basis for the accreted terranes, the orogeny, the petroleum resources, and the earthquakes of that segment of the continent.

The COCORP surveys in Michigan and Kansas probed a different kind of target. From gravity and magnetic information and meager drilling data it is known that a huge ancient rift (Figure 6), the result of east-west extension of the crust a billion years ago, traverses a large part of the mid-continent. The continent was, at that time, being pulled apart in the plate tectonic process. In Kansas, COCORP applied the seismic reflection

profiling technique to see into this great rift, and found a major block of crust, downdropped so as to form an asymmetric basin. The basin is filled with thick Precambrian sediments and volcanics. Some smaller secondary basins and other features were found as well. Precambrian rocks in the U.S. are not normally petroleum-producing. However, where Precambrian rocks of the rift outcrop in Minnesota there is a suggestion of petroleum occurence. Furthermore, some Precambrian rocks in the Soviet Union are productive of petroleum.

These facts, in conjunction with the COCORP observations, are apparently at least partially the cause of a recent leasing play in Kansas and adjoining areas. Furthermore, Texaco recently drilled a hole into the rocks of the rift in Kansas just 4 miles from the COCORP line. Whether this hole was drilled for information purposes or in the search for petroleum has not been revealed by the company, nor have the results of the drilling. However, this activity seems a clear-cut example of how a program designed to provide fundamental scientific information on the earth can have a substantial impact on industrial activities. Of course, I hope that at some later time Texaco or other companies will report that major discoveries of petroleum have been made in the mid-continent rift, and also in the deep rocks of Michigan as well. However, I am sure you are aware that wildcat drilling is only occasionally successful under the best of conditions.

In the Rio Grande Rift in New Mexico COCORP mapped a previously discovered magma body 20 kilometers below the surface and then found a similar feature in a subsequent survey in Death Valley. Whether such features may produce economic geothermal energy is yet to be determined. Seismologists have postulated a connection between the magma body and the historic earthquakes of New Mexico.

In the spectacular Basin and Range Province of Utah and Nevada (Figures 8 and 9), COCORP mapped features of the brittle upper crust that determine the characteristic appearance of this province, traced the apparently ductile lower crust over a huge area, and found a remarkably and perplexingly flat base to the crust beneath this highly deformed area. Some of the earthquakes of this province seem to be clearly related to features of the type COCORP has observed in the brittle crust. Others seem of a

different type not yet fully understood. At the western edge of this survey, in the Sierra Nevada, features of the deep crust that may be related to the famous Mother Lode gold deposit were found. If this association is demonstrated in subsequent surveys, a new means for understanding and for prospecting for similar ore deposits will be in hand.

The faults mapped at depth in the Sierras by COCORP are also of special interest in connection with the earthquake potential of that area because surficial geological evidence shows that the faults have been active recently. Thus as the tectonic story of this area becomes fully understood, it will be known just why and how these earthquakes occur.

Although in some cases the interpretation of seismic reflection data seems straightforward, particularly when it can be coupled with surface geoogical data, in other cases the data are enigmatic in the early stages and may not be understood until additional field studies are accomplished. This is bound to occur when only a tiny fraction of the object of study has been observed.

Consider the Adirondack Mountains of New York, for example (Figure 10). These beautiful mountains consist of formerly deep, old crystalline rock that has been domed up more recently. The younger, formerly overlying rocks have been eroded away so the old rocks lie at the surface. A COCORP survey in this area discovered a surprising feature, a prominent zone of parallel-layered, gently tilted rocks at a depth of about 20 km. What can those rocks be? Layered igneous rocks? Metamorphosed sediments? What is their relation to the rocks at the surface? How did these strange layered features get there? We can't answer these questions now, but with additional surveying we may be able to trace them to the surface where they can be identified, or else establish their configuration thoroughly so their history can be deduced. They may, in fact, be a key to understanding what happened when a still older ocean that preceded Iapetus opened and closed.

Here is one more intriguing observations (Figures 11 and 12). It was taken by COCORP within the last few weeks, and this is the first time it has been made public. Surveying revealed a very strong, almost mirrorlike, reflector in the crust beneath the coastal plain of Georgia. If such a

reflector were found by industry in a sedimentary basin it would surely be drilled, for a "bright spot" of this type is frequently caused by a major accumulation of hydrocarbons. The COCORP bright spot, however, is at a depth of 50,000 to 60,000 feet, about twice the depth of the deepest hole ever drilled for petroleum. Oil could not exist at these depths, although gas could. One hypothesis is that as Africa and North America collided, sediments were caught up in this giant vise and deformed in such a way that fluids, perhaps including natural gas in solution, were caught up and trapped in this particular place. If so, this observation and related observations tell us something important about the collisional process, and that is the role of fluids. The role of fluids in the crust is poorly understood but vitally important. Perhaps there is something of economic interest in the Georgia bright spot. Perhaps there are more such features. Although not necessarily earthquake-related, such examples of large and mysterious features tell us that we simply must continue and expand our exploration of the continental crust.

Figure 13 shows the history of COCORP exploration of the crust. In a decade of activity that began with only part-time field activity, COCORP has surveyed about 6000 km of line in 20 states. COCORP operates one crew full time, and the USGS now operates a crew part time to explore the deep crust. The petroleum industry operates about 500 such crews in exploration of the sedimentary basins of the shallow crust.

Figure 14 shows a schematic plan for a comprehensive survey of major crustal features on all continents. About a dozen countries have begun efforts to survey the deep crust using the seismic reflection profiling technique. As these surveys begin to produce this important kind of new information on the crust, one can safely anticipate the development of a fascinating story of the continents and how they came about.

This presentation is based on scientific material from a variety of sources, some published, but much of it not yet in print. I would like to acknowledge especially the assistance in its preparation of several members of the COCORP project including L. Brown, T. Hague, D. Nelson, and D. Wille.

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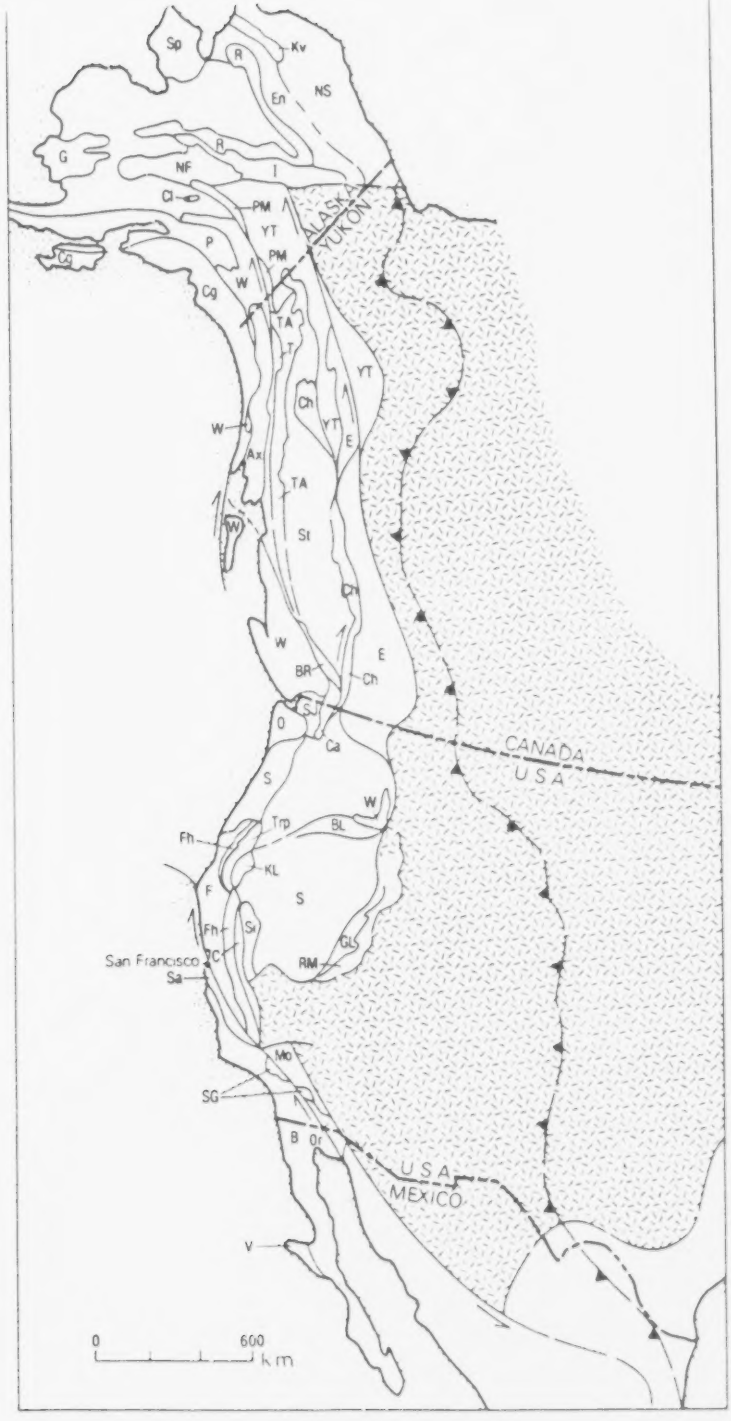

Figure 1. Areas designated by letters indicate the accreted terranes of the western U.S., Canada, and Alaska.

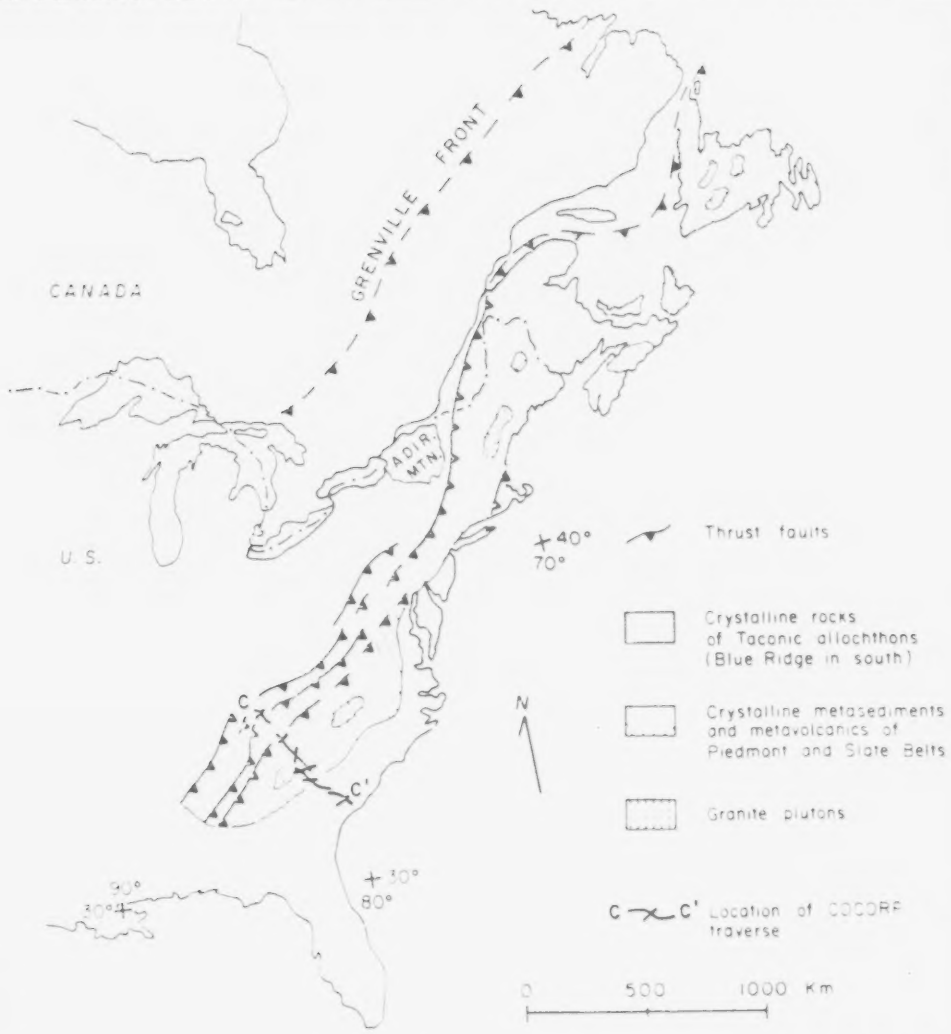

Figure 2. The first COCORP survey (C-C') and other features of the Appalachians.

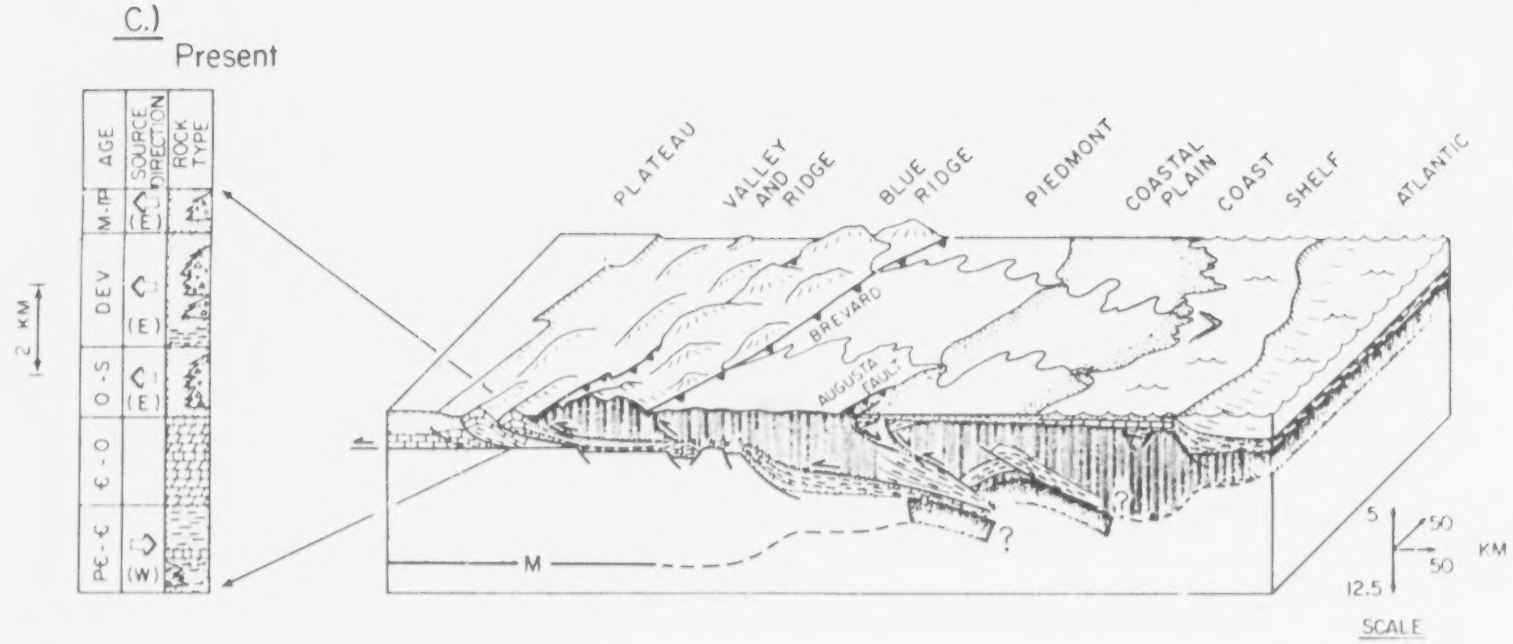

Figure 3. Block diagram illustrating the structure beneath part of the eastern United States. A thin sheet of rocks has been thrust from east to west over an early continental margin.

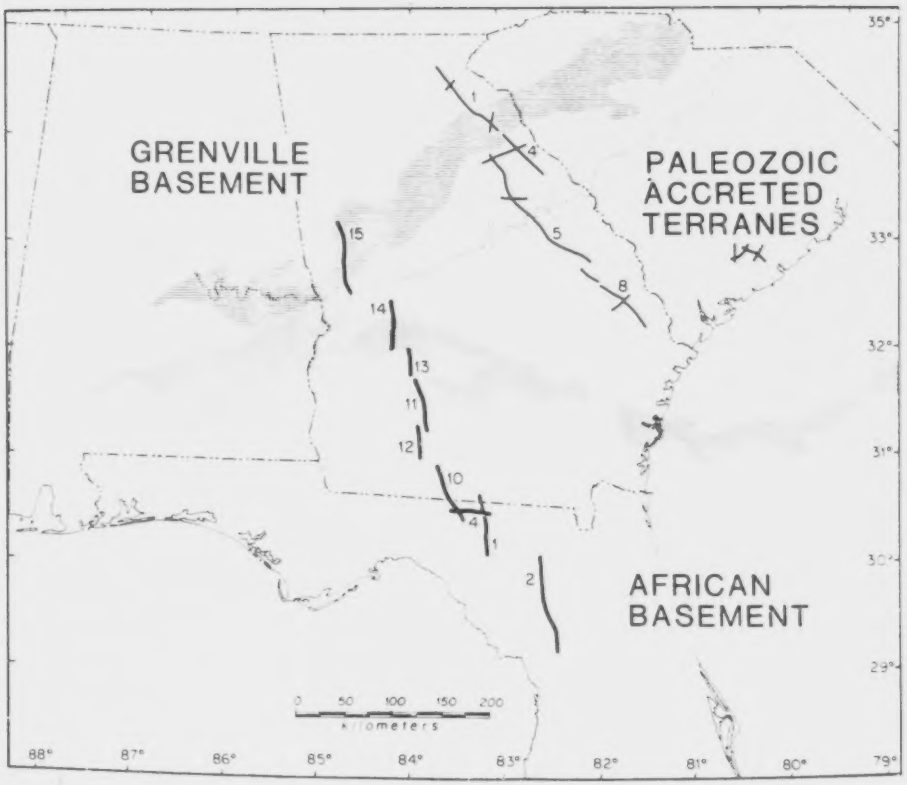

Figure 4. Heavy lines indicate COCORP survey lines crossing North America-Africa suture.

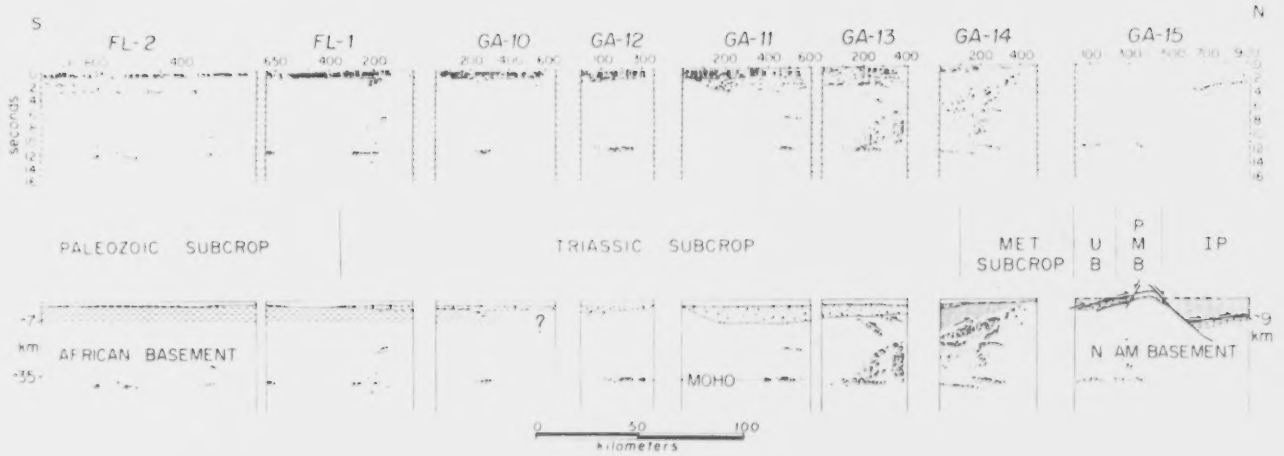

Figure 5. Sections illustrating COCORP data in Florida and Georgia. North America-Africa suture zone is evident on GA-13 and GA-14.

Figure 6. Index map showing COCORP surveys (heavy black lines) and Mid-continent Gravity Anomaly.

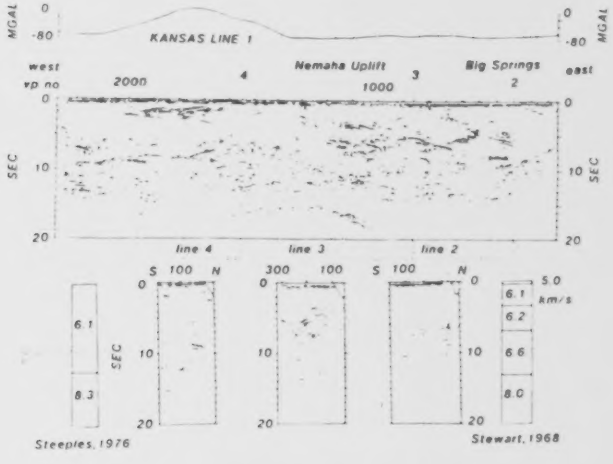

Figure 7. COCORP sections in Kansas. Rifted basin is seen between VP Nos. 1500 to 2000 from 0 to 3 seconds.

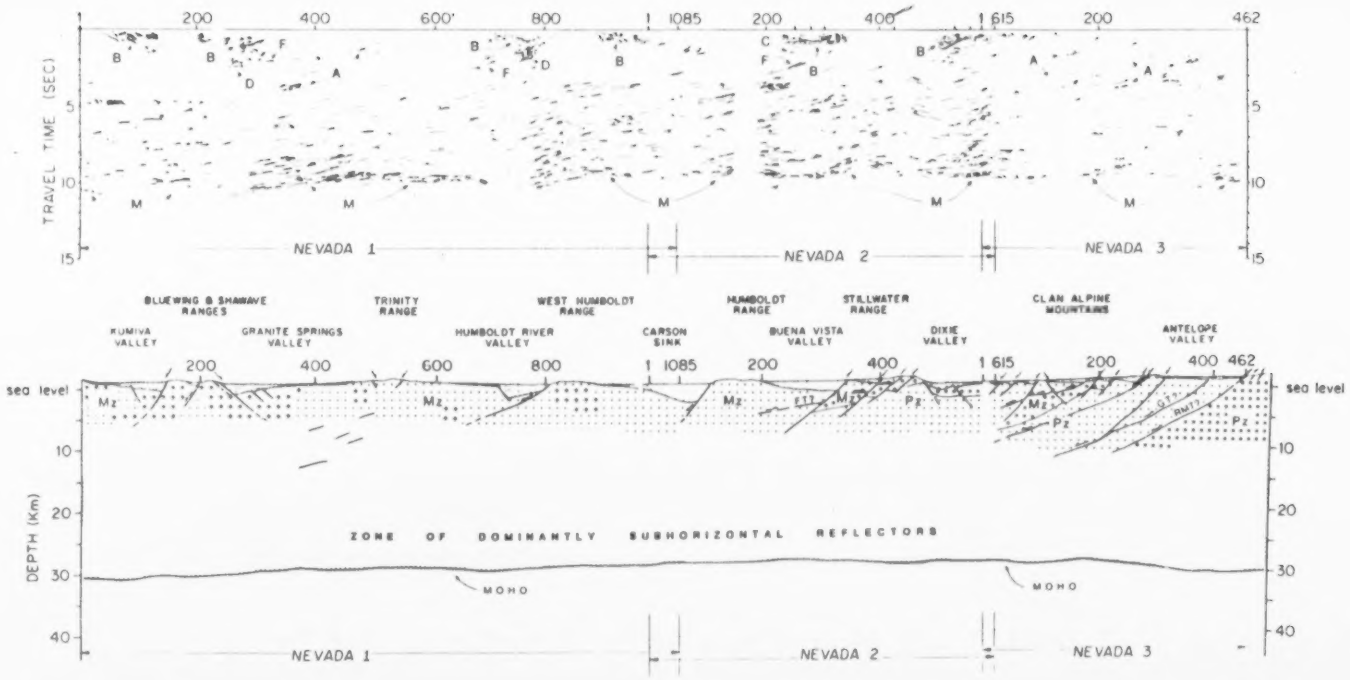

Figure 8. Part of COCORP traverse through Nevada. Upper section is a drawing of observed data. Lower section is schematic drawing of geology. Note rifted upper crust, ductile lower crust, and nearly flat Moho.

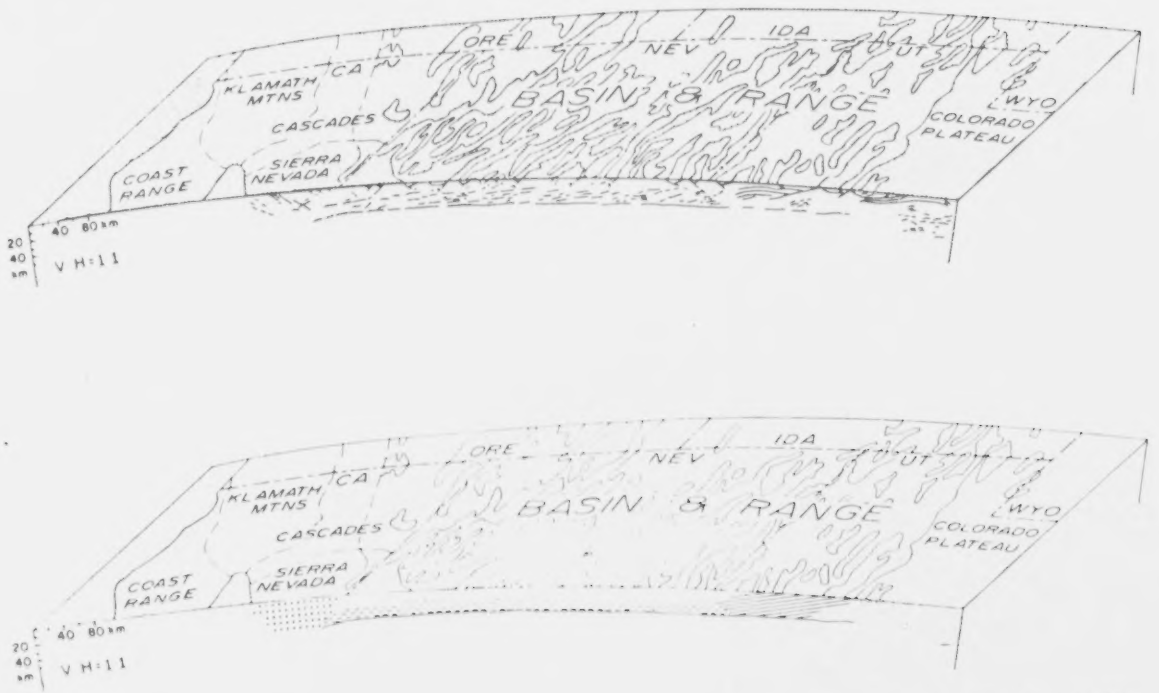

Figure 9. Block diagrams of parts of California, Nevada, and Utah. COCORP data shown schematically in upper section with generalization below. Note brittle upper crust, ductile lower crust beneath Nevada, major detachment faults in Utah, east-dipping faults in California.

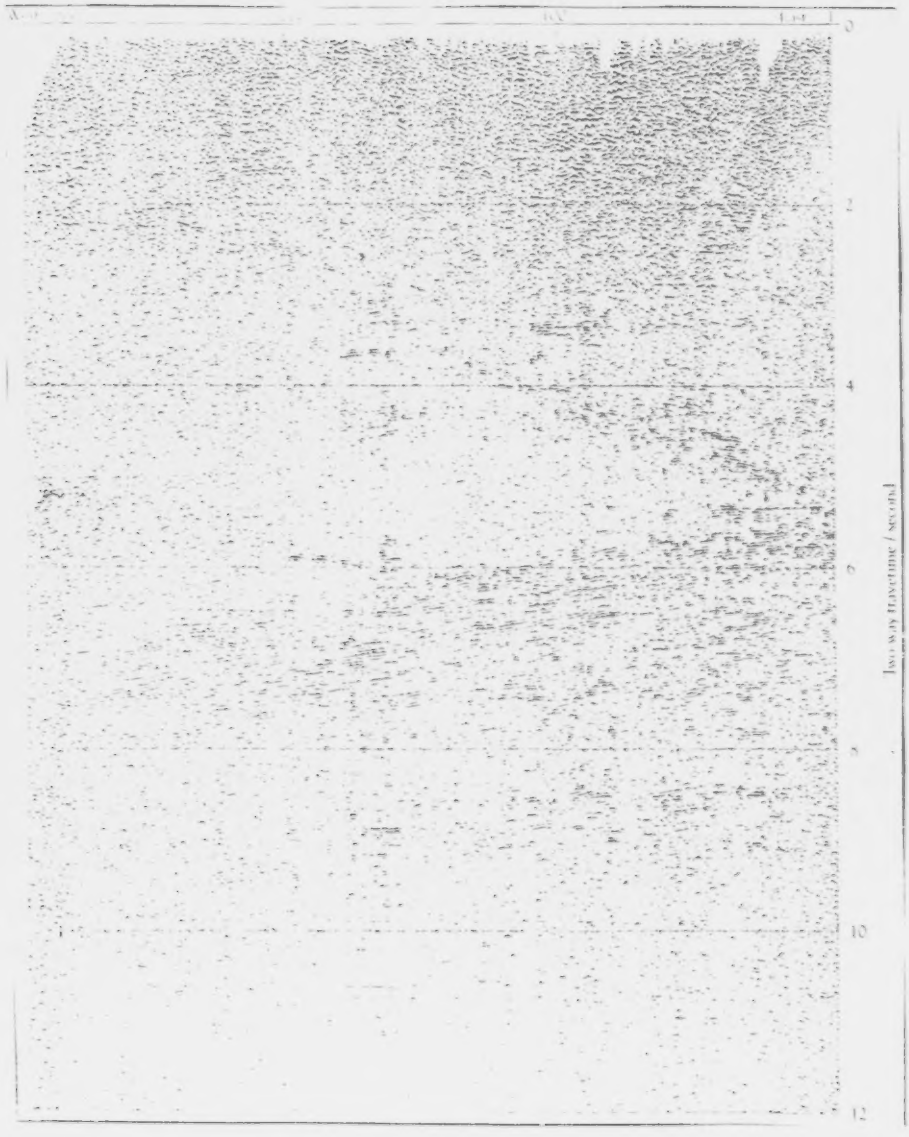

Figure 10. Section through the Adirondack Mountains of New York. Zone of gently dipping layered reflectors at depth is surprising and enigmatic in this limited survey.

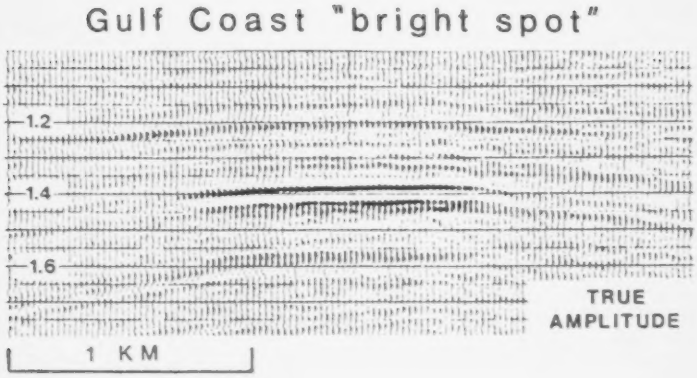

Figure 11. A typical industry "bright spot" from a site on the Gulf Coast. Note large amplitudes indicated by heavy black feature at a time of 1.4 seconds. Such features are commonly associated with hydrocarbons.

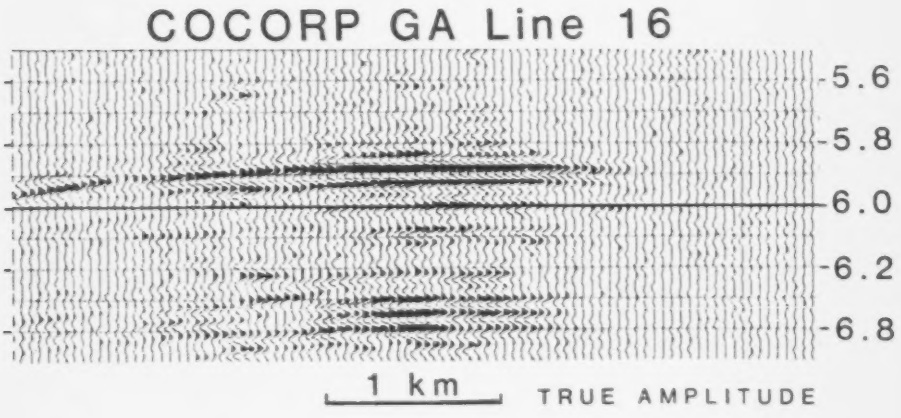

Figure 12. COCORP "bright spot" in Georgia. This feature is very similar to that of Figure 11, but it occurs at a depth of almost 60,000 feet, too deep for oil. This feature may be evidence for occurrence of fluids deep in the crust within the N.A.-Africa suture zone.

DEVELOPMENT OF COCORP DEEP SEISMIC REFLECTION PROGRAM

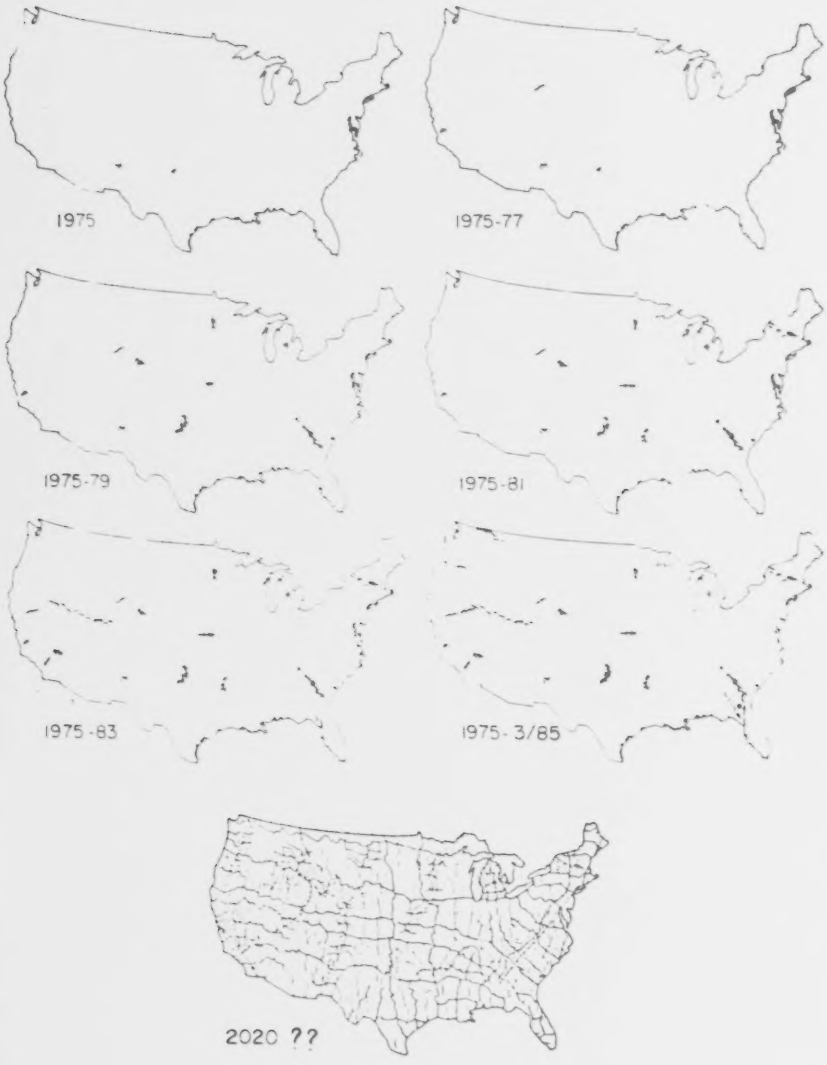

Figure 13. History of COCORP surveying and a schematic plan for comprehensive exploration of the crust of the U.S. through deep seismic reflection profiling.

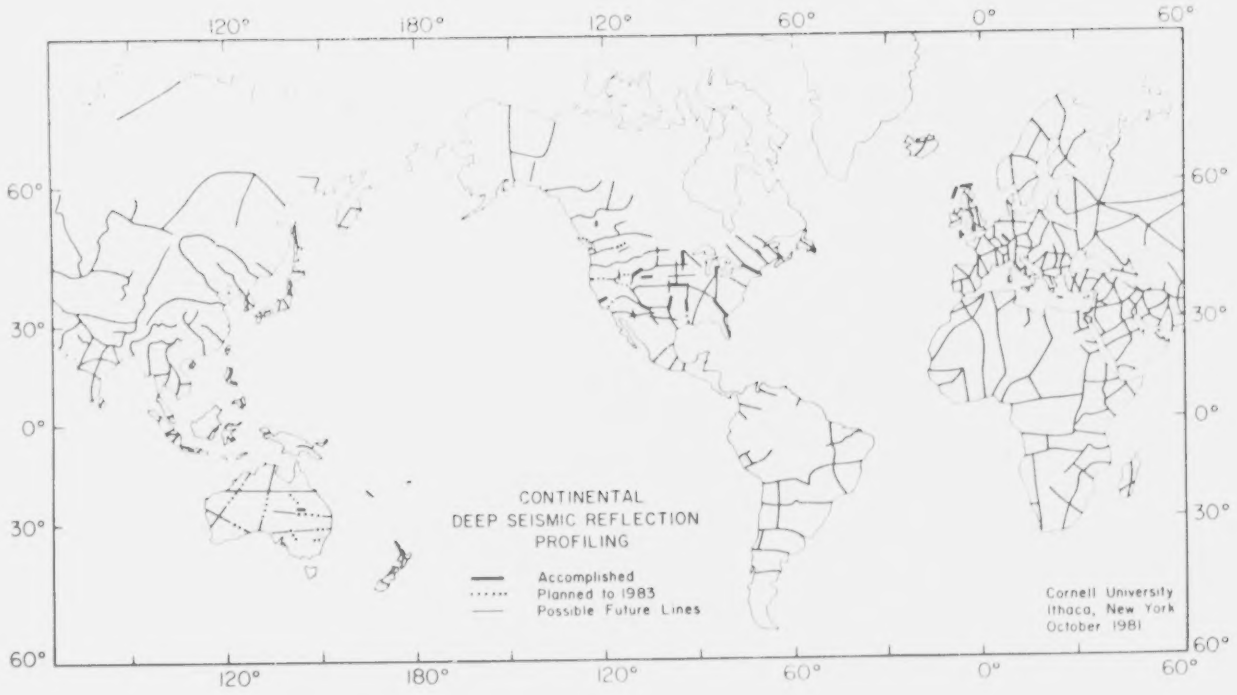

Figure 14. A schematic plan for surveying the continental crust the world over. This plan has been partly implemented (<1%) by scientists in a number of countries.

Mr. WALGREN. Thank you very much for that testimony. That's very interesting.

Let's turn then to Dr. Housner, please. We do find this an interesting subject and one that we don't often get a chance to have presented congressionally, so we're very curious and pleased that you are all here.

Dr. Housner.

STATEMENT OF DR. GEORGE W. HOUSNER, PROFESSOR EMERITUS OF EARTHQUAKE ENGINEERING, CALIFORNIA INSTITUTE OF TECHNOLOGY

Dr. HOUSNER. Mr. Chairman, I appreciate this opportunity to speak before the subcommittee. I have submitted a written testimony and am only going to paraphrase it in my spoken testimony.

I want to emphasize particularly the role of the great earthquake disaster. Now it's true that every earthquake is a disaster to the man whose house is knocked down by it, but some disasters are so large that they have a national impact; that is, through a large number of deaths, through extremely costly damage, through disruption of communication systems, transportation systems, military facilities, through disruption of manufacturing facilities.

Such a great earthquake disaster depends upon three elements. First, the earthquake must be sufficiently large. If the earthquake is too small, the shaking is not energetic enough to cause extensive damage. Second, the city must be close to the center of the earthquake because the intensity of shaking decreases with distance from the center of the earthquake. If the city is too far away, the shaking will have attenuated to a low intensity that will not cause a disaster. Third, the city to be unprepared.

If all three of these elements are in coincidence—namely, a large earthquake, close to the city, and unprepared for such a shake—then you have indeed a national disaster. A good example of that is the destruction of the city of Tangshan in China in 1976. This was a city of about 1 million people, a manufacturing city. An earthquake of magnitude 7.8, which is a very large event, occurred directly under the city. So it was a large earthquake, close to the city, and the city was, you might say, completely unprepared.

That city was located in a seismic zone of the building code which required no earthquake design. So you had here the extreme example of the three elements coinciding for a great disaster. And when the earthquake occurred, 75 percent of the structures in the city either collapsed or were so badly damaged as to be useless.

Over a quarter of a million people lost their lives, and the manufacturing facilities in that city—cement plants, steel plants, coal mines, and so on—were out of operation for long periods of time.

Many cities in the United States, you might say, are potential victims of a great disaster. Such large earthquakes do not occur frequently, but we have evidence that they have occurred, not only the western part of the United States, but in the Midwest and in in the western part of the United States, but in the Midwest and in none of the cities are adequately prepared for the worst that can happen, even in California.

Now, the Earthquake Hazards Reduction Act, the research that has been developed through it, has been very helpful. They're very valuable results. I would like to mention a few of them which in my opinion have been most important for the safety of cities.

First, there has been a noteworthy improvement in the ability to assess earthquake hazards in the sense of where earthquakes may occur and how large they might be.

Second, there have been also notable improvements in the design of structures to resist earthquakes, and particularly in what you might call high-tech projects, such as highrise buildings, offshore platforms, major dams, and other facilities which are costly enough to warrant the application of a high degree of expertise.

Third, there has been a notable advance in our understanding of dynamic soil failures; for example, such as soil liquefaction by intense ground shaking and this has been a very important aspect of constructing facilities to be able to resist earthquakes because, of course, if the soil beneath the facility loses its strength, then you have drift troubles.

However, the advances made by the research done through the Earthquake Hazards Reduction Act have certainly not solved the problem. To give you an impression of the magnitude of the problem, we have to consider that at present something between $200 and $300 billion a year is invested in construction in the United States. This is cumulative, so that you might say in the coming years, if you reach a steady state at that rate, there is something between $5 trillion and $10 trillion of construction in the United States which is exposed to earthquake damage.

So the problem is an enormous one, and I might illustrate the comparative smallness of our program in the United States as compared to what's being done, say, in Japan or in China.

We have looked into the—I am talking now about the earthquake engineering research, not seismological research—we have looked into this in those two countries, and we conclude that their budget for this sort of work is at least five times what ours is. And this is not including major experimental facilities which especially Japan has put an enormous amount of money into and is not including the earthquake preparation activities that are going on in those two countries.

In Japan, for example, in recent years they have been investing over a billion dollars a year in preparing for the earthquake which they are sure is coming just south of Tokyo. So that my feeling is that the program in the United States, while being very helpful and progressive, is not one which is going to solve the earthquake problem in the near future.

I looked over the FEMA 5-year plan, and while I certainly agree that it ought to be implemented, I think the general feeling in the earthquake engineering community is that it's on the low side, particularly since it doesn't include experimental facilities and extensive earthquake preparations.

There is no doubt that the Earthquake Hazards Reduction Act has been very valuable, and I think it will continue to be very valuable. It's just that in one sense we're pecking away at the problem. We're going much more slowly than we could if a more concerted effort would be made.

I am leaving with the subcommittee two books which show the damage that occurred in the China earthquake and that which occurred in the San Fernando, CA, earthquake in 1971. From these you will get an idea of what we're up against.

Thank you.

[The prepared statement of Dr. Housner follows:]

Testimony of

George W. Housner

to the Subcommittee on Science, Research and Technology
of the Committee on Science, Research and Technology of
The UNITED STATES HOUSE OF REPRESENTATIVES

March 19, 1985

RESEARCH NEEEDS IN EARTHQUAKE ENGINEEERING

My name is George W. Housner. I hold the position of Professor Emeritus at the California Institute of Technology in Pasadena, California. My special field of study is destructive earthquakes and the mitigation of their effects. In pursuit of these studies I have investigated earthquakes in the United States and in foreign countries and have performed research on earthquake effects. I am past-President of the Seismological Society of America, the Earthquake Engineering Research Institute, and the International Association of Earthquake Engineering.

I appreciate being given the opportunity of testifying before this Subcommittee on the subject of earthquake hazard in the United States and the need for related research.

No part of the United States is completely free of earthquake shaking, either from local earthquakes or from large distant events. For example, critical facilities such as nuclear power plants are designed for varying degrees of ground shaking, in all parts of the country. Although the most seismic regions of the United States are in the western part of the country (and Alaska), destructive earthquakes also occur in the midwestern and eastern parts, but at a much lower frequency of occurrence. This poses special earthquake problems for these regions.

The possibility of an earhquake disaster depends upon three things: 1) the occurrence of an an earthquake of sufficient strength to be potentially damaging; 2) that a city is

close to the epicenter of the earthquake, for if it is too far away the intensity of shaking will have attenuated to non-destructive levels; 3) that the city is unprepared for strong earthquake shaking so that structures and facilities are susceptible to severe damage. If the city is 100% prepared for that intensity of shaking then there will not be a disaster. On the other hand, there will be a disaster to the degree that the city is unprepared. None of the cities in the United States are adequately prepared for the worst that could happen, and in those regions where destructive earthquakes are expected to occur less frequently the cities are least prepared. This was demonstrated by the destruction of the industrial city of Tangshan, China by a magnitude 7.8 earthquake in 1976.

The city of Tangshan had about one million inhabitants plus another one-half million in the surrounding area at the time of the 1976 earthquake. A magnitude 7.8 event is a large earthquake that produces intense shaking in the epicentral region and, unfortunately, the earthquake centered directly under the city. The city was completely unprepared as the seismic zoning map in the building code showed it to be in a non-hazardous region and, as a result, no effort was made to provide earthquake resistance in structures, industries and facilities. When the earthquake occurred over 75% of the buildings either collapsed or were so severely damaged as to be unusable. Industries such as coal mines, steel plants, cement plants, railroad manufacturing, etc., were rendered inoperative, and several hundred thousand people lost their lives. Eight years later the rebuilding of the city is still underway.

The fact that potentially destructive earthquakes (magnitude greater than 6.5), do not occur so frequently in any region as to impose an immediate danger means that the probability of a disaster is small for any particular city and this poses

two special problems. Because of the relatively low probability of a disaster ocurring durring a 50 year period, the inhabitants of the city are willing 'to take a chance" and earthquake preparations are not undertaken. Although this approach may seem reasonable from the viewpoint of a single city it is not reasonable from a national viewpoint in which the safety of many cities over long periods of time must be considered.

A second problem is that it is not economically feasible to construct all cities to withstand, without damage, the maximum credible ground shaking that they might experience. This requires that the following objectives be adopted: 1) there should be no 'disaster' in the event of the maximum credible shaking; and 2) a certain degree of non-hazardous damage is acceptable for infrequent, large earthquakes, and the level of acceptable damage, depending on the expected frequency of occurrence, should be determined on an economic basis. The fact that construction in the United States is now at a rate of approximately 230 billion dollars per year indicates the size of the problem. The present state of knowledge is not adequate for the solution of the earthquake problem.

Satisfactory decision-making for earthquake safety and economy requires a reliable estimate of the frequency of occurrence of large earthquakes in the various regions of the country. Estimating an upper bound is not sufficient for these purposes. To implement such decisions requires the engineering expertise to design for controlled damage as a function of intensity of shaking and this requires a high level of understanding of the dynamic responses of structures to ground shaking and the ability of materials to withstand overstraining.

The present state of knowledge about the earthquake problem is not adequate. Further research needs to be done and this should particularly include: 1) research on the frequency of occurrence of potentially destructive earthquakes in the various regions of the U.S. and on the nature of the associated ground shaking; 2) research on the dynamic response of structures, facilities and equipment to strong earthquake ground shaking, with the objective of developing methods of designing for controlled damage. Since our cities are at present not well prepared it is desirable that research should also be carried out on coping with a disaster when it occurs.

The original "Newmark-Stever" report was prepared in response to a wide-spread feeling that research should be done on the problem of destructive earthquakes. This feeling was in part generated by the damage and loss of life incurred in Los Angeles by the M6.4 San Fernando earthquake of February 9, 1971. The Newmark-Stever report recommended a program of research and set forth three alternative levels of funding. The Earthquake Hazards Reduction Act which was then passed provided funding corresponding essentially with the lowest level of the N-S report, for the NSF Earthquake Engineering Research Program and for the USGS Seismological Research program. The Seismological Program's budget increased over the years as was prescribed in the EHR Act and is now approximately 34 million dollars per year. However, the Earthquake Engineering Program's budget did not increase as originally was prescribed in the EHR Act and is now at approximately 17 million per year. The lagging behind of the earthquake engineering research budget has certainly hampered the program. When comared with the 10,000 billion dollars that will be invested in construction over the next 50 years in the U.S. it becomes

clear that the present level of funding is unacceptably small for the problem it is trying to solve. In fact, comparing with Japan and China, it is found that the earthquake engineering research programs in both of these countries are many times larger than in the U.S.

It is unquestionable that a strong earthquake engineering research program can save many thousands of lives and many billions of dollars in future earthquakes, and I strongly recommend that funding be provided for earthquake engineering research that is at least comparable to the budget for the Seismological Research Program. An additional need for earthquake engineeering research is to improve the very inadequate state of the experimental research facilities now available to researchers. However. this requires significantly larger funding than that envisaged for the regular NSF-Earthquake Engineering Research Program.

Thank you.

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2. EARTHQUAKE ENGINEERING AND HAZARDS REDUCTION IN CHINA, SCPRC Report No. 6, National Academy of Sciences, 1980.
3. ENGINEERING FEATURES OF THE SAN FERNANDO EARTHQUAKE OF FEBRUARY 9, 1971, Calif. Inst. Tech., 1971.
4. THE GREAT ALASKA EARTHQUAKE OF 1964-ENGINEERING, National Academy of Sciences, 1973.

Mr. WALGREN. Thank you very much, Dr. Housner. We appreciate that, and we appreciate the books. Although they can't be made a part of the record, they will be made part of our library here, and we appreciate being able to use them as a resource.

Dr. Agbabian.

STATEMENT OF DR. MIHRAN S. AGBABIAN, CHAIRMAN, CIVIL ENGINEERING DEPARTMENT, UNIVERSITY OF SOUTHERN CALIFORNIA

Dr. AGBABIAN. Thank you very much, Congressman Walgren, and members of the subcommittee. I am honored to be invited to appear before your committee today.

I would like to talk about several items by paraphrasing the prepared statement that I have submitted. The first comment would be on the activities in the international field and our position with respect to other countries.

The second topic will be a comparison of the FEMA 5-year plan with the so-called Steinbrugge Committee, or the independent panel, report.

The third will be on the NRC [National Research Council] report recommendation on earthquake research facilities and instrumentation.

On the first topic, we had an international conference, a world conference, on earthquake engineering in July 1984, where more than 1,500 persons were present from 54 countries, and approximately 850 technical papers were presented from various countries. It was very clear in that conference, comparing our activities with those of other countries which were present, that we were indeed still considered the leaders in earthquake engineering research.

That sounds very encouraging, but the erosion of our leadership has already started. We have heard in previous testimony about other countries in building up their experimental capabilities, and examples were stated, such as Japan and the People's Republic of China. I will add to that countries like Yugoslavia and France and New Zealand, who are doing exemplary work in earthquake engineering research.

The question of international cooperation has been mentioned. I think that we can be very effective in technical exchanges with other countries, provided that we cooperate with them at an equal level. If it turns out that our leadership is not only eroded, but we're left behind, then the time will come when in the cooperative relationship the value of the technical exchange will diminish. When we are leaders, obviously we can chart the course of future research.

There are also implications of the competitive positions that are developing in the world market, especially in heavy construction in seismic regions of the world. Leaders in earthquake engineering technology are going to have the advantage of securing work in seismic regions where they will be able to provide earthquake-safe construction.

So there is a concern that our leadership could erode further unless we increase our emphasis on earthquake engineering research.

On the second point, the question of the comparison of FEMA's 5-year plan as compared to the independent review panel's suggested plan, I had the opportunity of reading both reports very carefully and making comparisons of their objectives and the overall scope of the plans. It is very clear that the two reports have comparable scope and objectives. They differ only in detail and not in the main thrust of their plans.

The FEMA plan appears to have used the independent panels work as a reference and built upon it the changes that they have introduced. These changes, as I stated, are changes in the sub-elements of the program. There are some omissions, some restructuring of the organization, and some minor additions in the overall plan. So we can say that as far as the objectives are concerned, and the scope, the two plans are not substantially different.

But when we come to the budgets, there are differences. The independent panel has two levels, level A and level B, budgets. Level B is approximately 60 percent higher than the level A budget. The FEMA proposed budget is much closer to the level A budget of the independent panel.

As to the effectiveness of the proposed budgets, it is quite clear from evaluating the degree of emphasis on various topics for research and investigation that the proposed budget that FEMA has submitted within the 5-year plan is a bare minimum just to keep the momentum of the program going. There is so much more that can be done to expedite the work to get earlier results. However, it seems that FEMA has selected a budget that, as I said, is a bare minimum. Anything less than that I think would have jeopardized the program.

The topic of the report published by the National Research Council is on earthquake research facilities and instrumentation. This report appeared in 1984. It was prepared and presented by an ad hoc committee of the National Research Council, in which they made several recommendations. And they prioritized these recommendations.

The highest priority, if I may quote from the report, states, "The Federal Government's earthquake engineering program should be the enhancement of the research and educational base in universities." There has been no disagreement to this. I think that anyone who has read the report would agree, as I have heard those agreements stated, that the experimental facilities at universities are becoming obsolescent, and unless their capabilities are enhanced, their research effectiveness will diminish. The report recognizes this.

Another recommendation refers to the so-called large-scale experimental capabilities. The FEMA 5-year plan recommends a study to be initiated. The independent panel, on the other hand, had stated that such a facility is a necessary part of the research capability of the Nation. The National Research Council's recommendation is similar to that of the FEMA 5-year plan, in that it says that as a highest priority or as step one in the sequence of steps we should initiate a study on the large-scale experimental facilities requirements.

My opinion is that it is not a question whether or not a large-scale experimental facility is needed, but that one should establish

what its characteristics should be, what its size should be, what its versatility should be, and what are the costs of construction and operation of such a facility. So the study should proceed, in my opinion, to establish these parameters.

One final point I would like to make is that in our discussions on earthquake research we hear comments such as, "You've been doing this now for so many years. How come you haven't solved the problem?"

And I think that it is not an appropriate question, because as we know, the title of the act is "Earthquake Hazards Reduction Act," and the question should be posed, "Have you been able to reduce the hazards, and how much have you reduced the hazard," rather than to ask whether or not the problem has been solved.

And I think that the answer to this question will come, in part, from the citizens who live in those seismic regions. They want to know whether the hazard that they are facing is being reduced by the effort expended. And my feeling is that the Earthquake Hazards Reduction Act and its provisions certainly are doing that.

Thank you very much.

[The prepared statement of Dr. Agbabian follows:]

PREPARED STATEMENT BY M.S. AGBABIAN, FRED CHAMPION PROFESSOR OF CIVIL ENGINEERING, UNIVERSITY OF SOUTHERN CALIFORNIA, PRESENTED TO HOUSE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

Congressman Walgren and members of the Subcommittee, I am honored to be invited to appear before your committee today. My name is Mike Agbabian, and I am Professor and Chairman of Civil Engineering at the University of Southern California, and President, for the past twenty years, of the consulting engineering firm of Agbabian Associates in California. Prior to accepting an academic appointment, I practiced as a professional engineer, and I have, therefore, a perspective that combines my experience as a practicing engineer and my present position in academia. I have also just completed my term of office as President of the Earthquake Engineering Research Institute which hosted the World Conference on Earthquake Engineering where more than 1500 persons from 54 countries were present, and 850 technical papers were presented on subjects covering seismic risk and hazard, earthquake resistant construction, and seismic codes and standards.

It is interesting to note that a compilation of the building codes of 33 countries shows that more than two-thirds were directly influenced by the seismic codes and standards developed in the United States, based on research and practice in American universities and consulting engineering firms. The world still looks to us for leadership in earthquake hazard mitigation, and the progress we have made since the enactment of the Earthquake Hazards Reduction Act of 1977 has been significant. It is, however, my conviction that unless we continue at the present level of effort as a minimum, our leadership will be eroded. In fact, there are areas of research in which other countries are moving ahead at a faster rate than we are, and they have either surpassed us, or are working at or close to our technological forefront. There are here implications of competitive positions developing in the world market of heavy construction in seismic regions. We can cite the superior experimental facilities in Japan, the experimental research in masonry construction in

Yugoslavia, the base isolation work of nuclear power plants and other structures in France, and the emerging technology, based primarily on planned experimental work, in the People's Republic of China. In addition, Japan has an intensive program of earthquake prediction and planning for postearthquake rebuilding that is a model for U.S. researchers.

I would like to offer my remarks in response to the specific points raised by Mr. Walgren in his letter of invitation to testify.

1. Funding levels and recommendations in FEMA's five-year plan as compared to the Steinbrugge independent review panel's suggested plan:

   A comparison of the two plans shows clearly that there is no fundamental difference in the thrust, scope and objectives of the main tasks. The differences are in the restructuring of some of the subtasks and the deletion of a few subtasks in the FEMA plan that appear in the independent panel's recommended plan. The FEMA plan appears to have been developed with the independent panel's plan as its reference. The five major tasks in both plans are identical in their total scope, and they differ only in detail. For example, the objective of Strong Ground Motion Recording and Analysis discussed as part of "Hazard Delineation and Assessment," is moved under "Seismic Design and Engineering Research," in the FEMA 5-year plan, but the scope remains essentially unchanged. The FEMA 5-year plan omits the conduct of earthquake prediction experiments in regions other than California, otherwise the earthquake prediction programs of both plans are essentially the same. FEMA is more specific on the plan for the National Earthquake Experimental Capability in that it limits the scope to a two-year evaluation study whereas the independent panel states that there is an indicated need for such a capability. The FEMA plan has an item in its objectives on Research

for Standards. This effort is implicit only in the independent panel's plans. A careful review of both plans indicates clearly that there are no major disagreements in the overall scope and thrust of the earthquake hazard mitigation program. The main conclusion we reach is the realization that both programs propose forcefully and without any hesitation a plan that can be implemented that is within the capability of the existing resources of the United States.

Funding levels in the two documents have major differences. The Steinbrugge panel has estimated two levels of effort, Levels A and B. Level B is approximately 60% higher than level A. The Level A fiscal budgets for '86 and '87 are within 1.3 and 5.7%, respectively, of the corresponding FEMA proposed budgets. There are some differences in the budgets of some of the program elements, but if one considers the restructuring of the main tasks in the FEMA plan, the budget differences appear only in the budgeting of subelements.

FEMA has placed next to all tasks an assignment of work by principal agencies, and the budget is also broken down into agency budgets. It is conspicous in this breakdown that although certain tasks are expected of NBS there are no allocations of funds to NBS to carry out its work.

In response to Mr. Walgren's questions on the adequacy of funding, I have two comments.

1. Although the Level B funding proposal is not necessarily an optimum budget, it recognizes the fact that a more accelerated effort is needed to reach useful results more expeditiously. On the other hand, Level A funding is a minimum budget for not losing the momentum and for continuing to obtain useful results for implementation in a

well coordinated earthquake hazard reduction program. FEMA has elected to propose a budget comparable to the Level A budget of the idependent panel. Anything less than that would be detrimental to the success of the program.

2. The second comment is on the distribution of the funds among the principal agencies in accordance with assignments of the program elements. It has taken several years to achieve a coordinated effort among the principal agencies. The roles have become better defined. NSF and USGS have clear goals in carrying out research. NSF's roles in promoting research in earthquake processes, earthquake engineering, and the socio-economic implications of earthquakes are well defined in the FEMA plan. So is the role of USGS in earthquake hazards monitoring and prediction research. FEMA and NBS, however, have had more complex responsibilities. It has taken some time for FEMA's lead-agency responsibilities and earthquake preparedness planning objectives to be clarified, and for NBS's effort of developing improved seismic safety provisions for use in the development of regulations to bear results. By zeroing the NBS budget, there will be disruption of the program in midstream. The burden of NBS's duties will fall on the lead agency who does not have NBS's resources. My comment on the budget distribution may also be taken as a comment on the important work delegated to NBS as the Federal agency that has the technical resources to coordinate and interpret seismic safety provisions for application to Federal buildings.

It is appropriate to refer to the title of the act when evaluating the work outlined for each agency.

The title reads "Earthquake Hazard Reduction." The degree of reduction achieved is proportionate to the effort expended in a well-planned program. Unlike research that is directed toward putting a competitive product on the market, earthquake research adds to knowledge that leads to further reductions of the hazard. It would be wrong to pose the question, "When are you going to solve this problem?" The pertinent question will be, "Is the hazard reduced to a level acceptable by our citizens who live in the seismic zones encompassing 39 states?" Today, we can categorically state that we are far from that goal, and the challenge to the Federal agencies and to the private sector is to diligently continue the work of hazard reduction that FEMA's five-year plan has outlined.

2. Earthquake Engineering Facilities and Instrumentation: The National Research Council (NAS/NAE) published a report in 1984 that (1) reviews the need for large-scale experimental facilities and instrumentation, (2) looks at the feasibility of meeting the perceived need, and (3) assesses the priorities for a U.S. program to fill the need. I have not heard any dissenting opinion on the highest priority the report has identified, namely "the federal government's earthquake engineering program should be the enhancement of the research/educational base in universities." The reason: "it will produce improved technical information as well as designers and constructors who have an increased capacity to build seismic resistant structures," Both FEMA's 5-year plan and the Steinbrugge panel recognize this. Another recommendation of the report reads, "The federal government should undertake, on an accelerated basis, planning aimed at developing a major national earthquake engineering experimental/test facility." As a first step, the

report recommends that a conceptual design study be initiated of a facility "capable of both dynamically and statically testing full- or nearly full-scale multistory buildings to destruction in a simulated earthquake environment." The FEMA five-year plan responds to this recommendation by proposing a two-year budget of 1.5 million total for an evaluation study with the notation that "allocation of funds is predicated on approval of NAS (NRC) report recommendations." It has been my firm conviction since 1982, having participated in a workshop on "Experimental Research Needs for Improving Earthquake Resistant Design of Buildings" that the computer is not a substitute for experimental research, but a necessary adjunct; together they provide the most powerful tool for earthquake engineering research. Small-scale models provide useful data, but important decisions for design and construction of critical facilities and buildings in seismic regions require large-scale experimental facilities. It is also my opinion, and I think many of my colleagues support it, that it is not whether or not a large-scale experimental facility is needed, but what are its characteristics, size, versatility, and cost of construction and operation. The proposed evaluation study should answer these questions.

Mr. Chairman, the Earthquake Hazard Reduction Act has both economic and humanitarian benefits. I am grateful for the opportunity to express to you my firm conviction that it is an extremely important legislation for the benefit of the United States and the world.

MIHRAN S. AGBABIAN

Mihran (Mike) Agbabian is chairman of the civil engineering department and Fred Champion Professor of Civil Engineering at the University of Southern California. Dr. Agbabian, a member of the National Academy of Engineering, is also president of Agbabian Associates, a consulting firm specializing in structural dynamics and earthquake engineering. He is past president of the Earthquake Engineering Research Institute, a national organization whose purpose is the advancement of the science and practice of earthquake engineering and the solution of national earthquake engineering problems. He is a Fellow of the American Society of Civil Engineers and member of the executive committee of the Structural Division.

Dr. Agbabian earned his B.A. in physics and B.S. in civil engineering at the American University of Beirut, Lebanon, his M.S. in civil engineering at Caltech, and his Ph.D. in structural engineering at UC Berkeley. He is a licensed professional engineer in civil, structural and mechanical engineering branches in the State of California. He is a resident of Los Angeles, California.

Mr. WALGREN. Thank you very much. We appreciate that.
Dr. Olson.

STATEMENT OF DR. RICHARD S. OLSON, ASSOCIATE PROFESSOR OF PUBLIC AFFAIRS, ARIZONA STATE UNIVERSITY

Dr. OLSON. Thank you very much, Mr. Chairman, for the opportunity to testify here. I wanted to apologize initially for not having a prepared statement to you ahead of time, but I was in Chile on a reconnaissance until Friday and then came home, packed, came here yesterday. So although it is here, it was not here the 3 days before.

I wanted to make four major points about the national earthquake problem in general, and the National Science Foundation's Societal Response Research Program specifically. The four points are as follows:

It is now widely recognized that the earthquake threat in the United States is national in scope, not simply a problem for California and Alaska. It's gratifying to note from all the other testimony that we seem to have buried that problem; we don't have to worry about proving that it's a national societal issue.

Two, attacking the earthquake threat requires a systems approach, combining engineering, geotechnical, and social science knowledge. Related to that is three, because earthquakes are increasingly recognized as a people and policy problem. The Societal Response Program at NSF is central—not peripheral—to any national effort to reduce earthquake hazard.

I am severely outnumbered in the room, but I would have to say that when you think about saving lives and protecting property, that only the first half of the issue is really engineering, architecture, and Earth sciences. We're talking about a public policy issue with serious political, economic, and social trade-offs to be made. So I am going to stake out, in a sense, for the social sciences the argument that it is at least half of the problem, and understanding it is half the solution.

Four, it would be easy for the various disciplines involved in earthquake research to separate and go their own ways, but this committee can help prevent that possible fragmentation.

To elaborate on point No. 1, it's obvious from everything we've heard today that recognition of the potentially serious earthquake problems in the Southeast, the Northeast, the Central States, et cetera, is evident. We don't have to worry about that. But from a public policy point of view, a very troubling aspect of the national earthquake problem is not only the significant population at risk, but also the number of important defense installations and economically key industries in areas of moderate to high seismic risk. This has to be considered. It's an artifact of the way the United States developed.

Look at the situation to see how acute it is, the State of Washington; South Carolina, especially in terms of defense industry and defense installations in South Carolina; California, and think again of defense installations and in the computer industry; and in the Boston area, an area of incredibly high high-tech growth.

Along this line, it is important to recognize that the Societal Response Program at NSF has supported various research projects on South Carolina, the Central States, Utah, and Washington, as well, of course, as California and Alaska. Areas of investigation have included public attitudes and public awareness, policy implementation, and political, economic, and social barriers to engineering and land use innovation.

My second point is that attacking the earthquake threat in the U.S. requires a systems approach to be successful. Only by combining knowledge from the Earth sciences, engineering, architecture, and the social sciences can we devise a mix of public policies and professional training that will bring a society through a major earthquake without it being a disaster. This is one of the strengths of the Societal Response Program and of the direction in which it has been evolving in the last few years, and that is the analysis of the barriers to the effective utilization of new as well as existing knowledge from engineering and the earth sciences.

A classical example here is Societal Response-supported research on the political, economic, and social obstacles to reducing the life safety threat posed by old weak buildings, brick, hollow tile, masonry, et cetera, which are the single greatest killer in any earthquake.

Third, earthquakes that occur in the middle of nowhere are of little interest except to the earth science community. Unless they strike a populated area, earthquakes are not disasters, they're just events. It's a societal issue. Therefore, the Societal Response Program is at the core, not the periphery, of research on earthquake hazard reduction, especially when the focus is on translating scientific and engineering knowledge into public policy.

Fourth, multidisciplinary research, which is what we're really talking about here, is easier said than done. Geotechnical and engineering experts deal with physical objects, but social scientists focus on people, organizations, and processes. We tend, therefore, to bother distress, disturb, anger some of our cohorts with such untidy and disturbing notions as vested interests, the necessity for political trades, organizational rivalry, and collective behavior.

As such, social science research on earthquake hazard tends to make few friends. But we are necessary to keep allied fields mindful of how complicated the real world is. And it's not so much that we have a monopoly on the real world and everyone else doesn't, but that there are different realities and the social scientist is going to ask different questions and operate from a different paradigm than our engineering and earth science colleagues. That is, we are sort of a necessary pain, healthy but bothersome, and because we make few friends, this committee is vital to the continued existence of a systematic multidisciplinary attack on earthquake threat.

Moreover—and finally—this committee knows better than any other that so-called scientific and technological issues rapidly develop major political, economic, social, and organizational aspects. Therefore, it is vital that this committee mandate the continued broad-based attack on earthquake hazard in the United States. And that has to include societal response research. Engineering and

geotechnical research must not proceed in isolation. The danger, I think, is tunnel vision.

We social scientists might raise uncomfortable and disturbing issues, but that makes us more necessary, not less. We may be a little unpopular, but I do think we're necessary.

Thank you.

[The prepared statement of Dr. Olson follows:]

Dr. Richard Olson, - Presentation

Let me begin by apologizing to the Committee for not having a written statement ready earlier for this hearing. The National Research Council, however, asked me to be part of the reconnaissance team to the current Chilean earthquake disaster, and I only arrived home on Friday.

I would like to make four major points about the national earthquake problem in general and the National Science Foundation's Societal Response research program specifically. My four points are as follows:

1. It is now widely recognized that the earthquake threat in the United States is national in scope, not simply a problem for California and Alaska.

2. Attacking the earthquake threat requires a systems approach combining engineering, geotechnical, and social science knowledge.

3. Because earthquakes are increasingly a "people" and policy problem, the Societal Response Program at NSF is central, not peripheral, to any national effort to reduce earthquake hazard.

4. It would be easy for the various disciplines involved in earthquake research to separate and go their own ways, but this Committee can help prevent that fragmentation.

To elaborate, we now know that earthquake hazard in the United States is not restricted to one or two states. To those in California and Alaska must be added potentially serious earthquake problems in the Southeast; the Northeast; the Central States, especially Missouri and Tennessee; Utah; and the state of Washington. A very troubling aspect of the national earthquake problem is not only the significant population at risk, but also the number of important defense installations and economically key industries in areas of moderate to high seismic risk. The problem is especially acute in Washington, South Carolina, California, and in the Boston area.

Along this line, it is important to recognize that the Societal Response program has supported various research projects on South Carolina, the Central States, Utah, and Washington, as well as California and Alaska. Areas of investigation have included public attitudes of awareness, policy implementation, and barriers to engineering and land use innovation.

My second point is that attacking the earthquake threat in the United States requires a systems approach to be successful. Only by combining knowledge from the earth sciences, engineering, architecture, and the social sciences can we devise a mix of public policies and professional training that will bring a society through a major earthquake without it being a "disaster". This is one of the strengths of the Societal Response program and of the direction in

which it has been evolving: analysis of the barriers to the effective utilization of new as well as existing knowledge from engineering and the earth sciences. A classic example is NSF-supported research on the political, economic, and social obstacles to reducing the life-safety threat posed by old, weak buildings, the single greatest killer in any earthquake.

Third, earthquakes that occur in the middle of nowhere are of little interest, except to earth scientists. Unless they strike a populated area, earthquakes are not disasters, just "events." Therefore, the Societal Response program is at the core, not the periphery, of the research on earthquake hazard reduction --- especially when the focus is on translating scientific and engineering knowledge into public policy.

Fourth, multidisciplinary research is easier said than done. Geotechnical and engineering experts deal with physical objects, but social scientists focus on people, organizations, and processes. We tend, therefore, to bother our cohorts with such untidy and disturbing notions as vested interests, political trades, organizational rivalry, and collective behavior. As such, social science research on earthquake hazards tends to make few friends, but we are necessary to keep allied fields mindful of how complicated the real world is. That is, we are sort of a necessary pain, healthy but bothersome. Because we make few friends, this Committee is vital to the continued existence of a systematic multidisciplinary attack on earthquake threat.

Morever, this Committee knows better than any other that so-called scientific and technological issues rapidly develop major political, economic, social, and organizational questions. Therefore, it is vital that this Committee mandate the continued broad-based attack on earthquake hazard in the United States, including Societal Response research. Engineering and geotechnical research must not proceed in isolation. We social scientists might raise uncomfortable and disturbing issues, but that makes us more necessary, not less. Thank you.

BIOGRAPHICAL SKETCH

Dr. Richard Stuart Olson is Associate Professor in the School of Public Affairs at Arizona State University. His experience includes membership on the disaster reconnaissance teams in Managua, Nicaragua (1972), Guatemala (1976), and very recently Chile (March 1985). His special interests are the political, economic, social, and organizational problems which affect the translation of scientific and engineering knowledge into public policy. He is currently finishing a two-year project on the policy dilemmas of earthquake predictions made by U.S. scientists for foreign countries.

Mr. WALGREN. Thank you very much, Dr. Olson.
Dr. Wiggins.

STATEMENT OF DR. JOHN H. WIGGINS, PRESIDENT, J.H. WIGGINS CO., AND CONSULTING PROFESSOR, STANFORD UNIVERSITY

Dr. WIGGINS. Thank you, Mr. Chairman. My name is John Wiggins. I am a senior scientist with the J.H. Wiggins Co., a firm I founded about 19 years ago and which is now wholly owned by National Technical Systems. I am also a consulting professor at Stanford University.

I would like to say at the outset that I echo Dr. Olson's comments. In other words, because I come to you as a scientist and engineer—I hold degrees in geophysics, physical sciences, civil engineering, structural engineering, as well as business administration—I don't think my views are parochial in nature. And I couldn't echo his comments more.

I am here to answer principally the five questions that you posed in your letter to me, which I received something like on Wednesday, and I have put these comments together since then.

Mr. WALGREN. We apologize.

Dr. WIGGINS. No, that's quite all right, it's just that I received it on Wednesday and I am going to respond to your questions. I would like to highlight that I am responding to them as a person and as a firm, who in 1974 wrote what I think is just about the first public policy report on the subject, wherein our report was the only one referenced in the first version of the 1977 Earthquake Hazards Reduction Act.

Therein, we examined the losses to the year 2000 that could ensue, from earthquake—also the public policy issues and so forth and so on. In other words, I could have answered Mr. Boehlert's question about where New York stands in the loss picture: It's ranked about fourth of all the States for example, as far as loss, the annual loss picture.

I come at it from this perspective, I have been in the natural sciences since 1953. I have been around the Horn. I have worked in technologies from the supersonic transport and the DC-10 failure analysis. We were the only firm ever contracted to make a public policy examination of what to do about the DC-10. Remember when that failed in 1979. Do you let it fly on the one hand or do you ground it for 2 years and recertify it on the other. Look at the consequences?

So we have been in that business, coming from a technologic perspective. So I am going to answer your questions from that perspective.

First, to comment on the adequacy of the budget. We examined this in 1974, and we gave some recommendations at that time. Putting it into current-day dollars, we see the numbers should be, instead of $70 million a year, about $160 million a year. If you want a number, that's the number. And we can justify it. We can justify it based on the amount of work that has been done in research, believe it or not, in the Department of Agriculture.

When you look at hybrid corn and sorghum and those things that result from research from 1915 to 1955, the amount of money

that was spent in that research and the payoff that was received, again beginning about 1933—research started in 1915, roughly about a 700-percent return.

When you look only at the costs or, let's say, the losses that would ensue from a major significant event—and there have been about 4 in the last 300 years since this Nation has been populated, return period about 1 every 75 years—looking at $70 million times 75 years—I am not discounting for any thing—we see that we're looking at about 1.5 percent is what we're talking about in terms of the losses, the losses being about $90 billion.

My firm conducted a study for the insurance industry sometime ago. In direct losses, about $30 billion, in infrastructure losses, about $30 billion in losses. We're just trying to figure out about $30 billion additional.

For example, our Nation is run by computers. These computers are not mounted for earthquake. Just think, for example, Mobil refinery in Torrance, CA, does a $1.3-billion-a-year throughput in business. They're not doing a doggone thing regarding earthquake mitigation, yet their whole refinery is run by computers. But they're not doing anything. There is no implementation act to make them do anything. And they're not going to do it.

Yet we have the whole city of Los Angeles around us. Remember Bhopal. What "Bhopal" is going to be happening in the United States as a result of this earthquake situation?

So when you look at the budget situation, you can't look at it strictly from the standpoint of what losses it's going to mitigate that we can account for. How about those losses that we can't account for. We have not conducted the kind of research that would answer these questions. That's point No. 1.

Point No. 2 was already mentioned in earlier testimony. When you earthquake-design a structure, not only do you get something for that, but you do something for the wind loading, you do something for the landslide loading. In other words, you're getting payoff in other areas.

Point No. 3. My firm did the first Earthquake Hazards Reduction Program in the city of Long Beach in 1971. This is before we even had any money.

Remember, the Earthquake Program hasn't really had any research money before 1972. Yet in 1964 I was at the Seismological Society of America annual meeting, and there were 35 of us and all 35 of us were talking to each other. You know, we're doing it on our own—little internal funds. We had no money. So really the money has only started coming after 1972–73. What you've seen is the results of what has been happening since 1973 on.

In the city of Long Beach, 1971, old unreinforced masonry buildings had to come down. But what has happened is they are very happy with this program—the city of Long Beach—because their tax base has almost doubled. As new structures have come along, the whole city has rejuvenated, to a certain extent because of the Earthquake Reduction Program that we've done.

So you can't look at the payoff from this research as simply being, "We're going to reduce these losses." There is a greater and synergistic payoff that will happen in various social, political, legal, and economic consequences. And we have not included losses from

liability. I mean people are going to get sued. Lawyers are going to have a field day, believe me.

Those are my comments on the budget. My next comment is on the long-range implications of the budget.

You look at the budget that I saw in the FEMA program that shows that it grows 10 percent in 5 years. Considering that, say, if this country still grows about 4 percent per year in real growth, the inflation rate holds at 4 percent real growth, the Earthquake Reduction Program will be reduced by 37 percent in current dollars. So actually, that budget that was produced is a reduction program.

If what I said before applies, what I am saying now is that you're reducing the program. In other words, you're going to pay for it one way or the other because if an earthquake happens tomorrow that's a big disaster, believe me, this program will be funded very well. Not only that, you'll have the cost of the disaster.

So you're going to pay for it like the old Fram filter ad on TV. The oil filter ad, you know, "Pay me now or pay me later." You're going to pay $5 now for the filter or you're going to pay for a whole engine job later on. So that's the long-range implications.

Regarding the appropriateness of the distribution of funds to meet the goals of the National Earthquake Reduction Program, I have listed some things down there, and I see that approximately half is aimed at mitigation, which I would say is in the passive role as opposed to the active role that the Federal Government could take. I am going to speak to that a little later on. And the balance is in research, which I think is an appropriate balance. I would like to see a little more active participation by the Federal Government, however.

I am going to read my testimony regarding the folks that are doing the work; namely, FEMA, NSF, USGS, and the National Bureau of Standards. And I am going to speak principally about the National Bureau of Standards.

I note the National Bureau of Standards Center for Building Technology is given no role in the program from 1986 on. I believe this to be a serious error for the following reasons:

One. The National Bureau of Standards is the principal link between the research engineering community and design practices. Codes, in and of themselves, don't mitigate a thing. There also must be design practices, construction practices, and administrative practices that accompany the codes.

Further, codes are built by volunteers, many of whom are pushing their own materials or methods, funded by their companies or organizations. I sit on these committees. I have seen them. They, for the most part, do not have the overall national perspective in view. Only the National Bureau of Standards has this national engineering perspective, ranging from research on the one hand through design and administration and construction to quality control on the other.

In other words, you can have a nice code. We studied the State of Utah with regard to the number of principals within the building departments that can actually administer the code. Sure, the State has adopted the building code by reference, but there is not one who understands how to apply it, not one person. When we worked

with the Seismic Safety Commission of the State of Utah in developing a rehabilitation code for those people, we made a survey of all of the building officials. They can't administer. So just having a code doesn't mean you've got safety.

Finally, remember that earthquakes don't kill people, it's the structures that fall on them that, by and large, principally are the cause for these losses.

Two. The Center for Building Technology has a host of highly qualified engineers, many of whom are nationally prominent in their professional fields. To eliminate the activities of these people from the Earthquake Hazards Reduction Program therefore would be a serious loss that could not easily be regained. You've got a tremendous resource here.

Three. Many of the National Bureau of Standards engineers are involved heavily in international professional organizations aimed at mitigating earthquake and other hazards. This can only bring synergism to this country. I have worked with Yugoslavians, for example, as Mike mentioned earlier, and found them to be very creative and have a number of good ideas which I brought home to the United States.

For example, I brought home their building damage categorization procedure. We had one, but it wasn't very good. Theirs was much better.

But without an authoritative functional base such as the National Bureau of Standards, 99.9 percent of my reports about such matters, like most such research reports, simply sit on the shelves of other researchers. However, the weight of the Bureau can bring international information into the U.S. arena. Not me. It has to be the Bureau.

Four. Unbeknownst to many people, the National Bureau of Standards is the only engineering research facility within the Federal Government aimed at the construction industry. This industry, which represents almost one-tenth of the gross national product, is tremendously fractured. To expect that the private industry will take up the role for the Center for Building Technology in the Earthquake Program is not only wishful thinking, but is also impossible.

There is no General Motors of the construction industry. There are, of course, large companies who either make glass, make steel, or make wallboard and the like. But none of them looks at the composite structure, which is made up of all these materials, in order to take research knowledge from universities, link it together, and put it into practice for composite construction of buildings, bridges, highways, and the like.

This building is made up of—just take a look in this room—different elements. And you mean to say that the steel industry is going to do something for concrete construction? No, sir; they compete with one another.

Five. Like the NASA research laboratories in the space business, the National Bureau of Standards stands as the single and sole organization of its kind within the Federal Government. How would Boeing alone have put a man on the Moon? How would North American-Rockwell alone put the recoverable shuttle into orbit? Only through cooperative research and engineering between Gov-

ernment and private practice, as well as universities, were these feats accomplished.

In my opinion, the Earthquake Hazards Reduction Program will be seriously hampered if the National Bureau of Standards does not continue not only to be involved but to have a larger role in the engineering, design, and analysis work that must take place if we are truly going to mitigate earthquake hazards. For example, I would like to see them get more into this toxic substances business. We have petrochemical companies, we have chemical firms, we have refineries, all of these things in highly metropolitan areas.

Very little is being done about the hazard or catastrophe that could result from these kinds of things under the Earthquake Hazards Program. And the city of Torrance doesn't really have much control over the thing. You've got to look at the local parochial control. They don't have the control. But the Federal Government, believe me, has more statutory regulatory authority right now. You don't even have to pass any laws. And I am going to discuss that further.

Differences in the funding levels and the recommendations made in the FEMA 5-year plan versus the Steinbrugge independent review panels. I haven't read the Steinbrugge panel report, so I can't comment.

Comment on the recommendations made by the National Research Council's report, "Earthquake Engineering Facilities and Instrumentation." I was a member of that panel along with Dr. Housner. And I agree with the recommendations, with one caveat. And that has to do with the big shaking facility.

First, I think we as Americans should recognize that the rest of the world views us as what we are because of our imagination. Now, there are other imaginative ways of looking at full-scale situations other than a big shake table, in my humble opinion. And I would like to see a feasibility study conducted on the many other ways that it could be done a lot cheaper.

Second, if viewed within the $70 million a year budget only, I would recommend highly against the big shake table, because it would drain so much money from the rest of the program. It only affects one part of the program that looks at how engineered facilities perform as a system. And we know quite a bit about how to design these structures right now. In other words, it would answer primarily earthquake engineering research questions. But if viewed in the larger context of the budget I proposed earlier, then I highly support that facility.

So from my perspective if you're going to look at the whole budget, I say don't do it. If you're going to augment our budget, then give it a big roll.

Last, you have asked me to comment on any other issues. And I am going to read this one, too. In 1981 my firm completed a $121,000 study for the Federal Insurance Administration regarding what that administration's involvement in the Earthquake Insurance Program should be, if any. The conclusions of that report were misinterpreted, since in fact we made no conclusions. We only listed a series of alternatives.

We wanted to conduct a workshop which would rank order the conclusions, using a number of interested and affected parties.

However, the Office of Management and Budget would not allow the expenditure of $16,000 additional to conduct that workshop, since I was told that anything that smacks of Government regulation is not to be funded.

I highly support the notion that there have been many regulations passed in the 1970's that were not cost beneficial. That does not mean that we should throw the baby out with the bathwater.

The issue of earthquake insurance could be a very important mitigating tool in the Earthquake Hazards Reduction Program. And it would require no new tools. Today the Federal Deposit Insurance Corporation, the Federal Savings and Loan Insurance Corporation, the VA, the FHA, the Internal Revenue Service, and many other Federal organizations carry with them a large degree of statutory authority wherein they could require earthquake insurance on moneys insured or guaranteed. The IRS could allow deductible items on those moneys that were spent for rehabilitation or earthquake insurance.

In other words, there are many carrots and sticks that the Federal Government can provide today toward earthquake hazards mitigation which would require little research other than socioeconomic consequences.

It is important to conduct the type of research that are proposed in the FEMA-NSF-NBS-USGS document. However, there are other areas for research and implementation—this is the big word—"implementation" that should be studied and budgets augmented. It is the area of social and fiscal policy, public policy that I am speaking.

If the act truly is a mission to mitigate earthquake loss, rather than fund research that carries with it the hope that mitigation will result, I suggest that social public policy and fiscal policy areas be seriously addressed so that we can proactively begin the Earthquake Mitigation Program now.

Thank you very much.

[The prepared statement and letter for the record of Dr. Wiggins follow:]

TESTIMONY OF
JOHN H. WIGGINS, PH.D.*
SENIOR SCIENTIST
NTS/J.H. WIGGINS COMPANY

Before the Subcommittee on Science, Research and Technology, Committee on Science and Technology, U.S. House of Representatives, March 19, 1985.

Mr. Chairman:

My name is John H. Wiggins. I am a senior scientist with National Technical Systems/J.H. Wiggins Company, a company which I founded nineteen (19) years ago and have recently sold to National Technical Systems. I am also a consulting professor at Stanford University in the Department of Civil Engineering. My educational background includes degrees in Physical Sciences, Geophysics, Civil Engineering and Business Administration. Therefore, I believe I am qualified to speak on the total earthquake hazards reduction picture from the earthquake science to the engineering research and practices that derive from science. I am also a registered civil engineer, safety engineer and geophysicist as well as a certified professional geological scientist. Thus, the area of professional practice is included in my experiencial base. Finally, I have worked on such broad technologies ranging from nuclear radiation, biophysics, the supersonic transport, the Alaska pipeline, liquid natural gas facilities, oil well drilling research, D-10 failure analysis, and many others in addition to earthquake engineering research and professional engineering services which are included in my background. In 1974, we developed what I consider to be one of the first public policy analyses on the earthquake situation, a justification for earthquake engineering research budgets for the National Science Foundation. This report was later cited in the first draft of the Earthquake Hazards Reduction Act of 1977.

My testimony today will be predicated on how I interpret the Earthquake Hazards Reduction Act of 1977. I believe it to be principally a mission-oriented Act which includes research. In other words, the Act primarily is intended to mitigate or reduce the effects of earthquake and, consequently, the losses that would ensue. Of course, in order to do this, one must conduct research just as NASA in developing Apollo and the Space Shuttle needed to conduct research at its many laboratories and through its many contractors in order to place a man on the moon and place a recoverable vehicle into orbit. Nevertheless, the principal

*Consulting Professor, Stanford University.

theme on which I shall base my testimony will be that of mitigation and the specific basic and applied research aimed at influencing mitigation strategies, procedures and methods. In so doing, I shall address the subjects mentioned in your letter dated March 4, 1985.

Comment on the adequacy of the overall (Earthquake Hazards Reduction Act) budget:

I feel extremely well-qualified to comment on this subject since my firm in 1974 developed the first study aimed at developing a specific budget for research on earthquake hazards reduction. Speaking in broad terms, I shall make my comments to this question as follows.

Consider the fact that, within the conterminuous United States over the last three-hundred years, there have been four maximum credible earthquake events which have taken place, three in California and one in southeastern Missouri. (A fifth occurred in Alaska in 1964 but I shall be conservative and not include it in the analysis to follow.) This indicates to me that there is an average return period for an extreme event somewhere within the conterminuous United States of seventy-five years. My firm has estimated for the insurance industry that roughly $30 billion could be lost in direct losses to structures from such an event. An additional $30 billion could be lost by the infrastructure and from secondary and higher order consequences. Yet, an additional $30 billion may be lost from implications to the stock market, lost taxes, business interruption and other higher order losses resulting principally from malfunction of computers which influence our lives today. In other words, an extreme earthquake can influence the GNP growth rate of the nation, as the Japanese found after the Kwanto earthquake of 1923. It took Japan 10 years for the GNP growth curve to recover after that event. We are, therefore, looking at approximately $90 billion in economic losses, direct and indirect, which may occur once every seventy-five years on the average (not counting Alaska and Hawaii).

An annual budget of $70 million over that seventy-five years results in a 6% cost/loss ratio simply for research and mitigation efforts aimed at this single scenario event. Out of the entire spectrum of earthquake, however, the extreme scenario events only cause about 25% of the total losses that can be expected from smaller earthquakes. Therefore, looking at the total loss scene, the budget which is before Congress today represents about one and one-half percent of the losses they are intended to mitigate, not including life loss.

When it is recognized that the earthquake mitigations that would result from the Act spill over into landslide and hurricane problems as well,

there can be an extremely large payoff of mitigation of other hazards that rival the earthquake from the standpoint of the annual loss picture. Looking even further, we have found that the application of an earthquake rehabilitation ordinance in the City of Long Beach, California (which my firm was responsible for back in 1970) has actually caused the city to become financially stronger with the abatement of existing hazardous structures and the construction of new, larger and more desirable structures. It has indirectly caused the tax base of the city of Long Beach to be much stronger. Thus, earthquake hazards abatement programs sponsored by the federal government can actually be a boon in many ways provided we know how to do it, when to do it and where to do it.

In our 1974 report we used a number of procedures to estimate the total value of an earthquake research budget. We correlated such things as the social and financial returns versus the research dollars spent on the development of hybrid corn and sorgum. Depending on the rate of interest at which one would discount future returns, various researchers arrived at rates of returns ranging between 200-700%.

Also the time frame used in the hybrid corn case was from 1910 to 1955 and the returns from the research only began after 1933. Thus, one cannot expect a lot of returns from the research in the Earthquake Hazards Reduction Program for some time.

However, translating the numbers from our 1974 report into current 1985 dollars, I would compute an expenditure of about $160M per year as the optimum budget for the United States. This number is, of course, in excess of the $70M currently contemplated for authorization.

We can examine the adequacy of the budget also from the perspective of what other nations are doing. In Japan they are spending about $1B per year for a country with 40% of the gross national product of the United States. In China they are spending about $500M per year for a country with about 12% the gross national product of the United States. Granted these countries have different perspectives about the earthquake situation having experienced serious losses over thousands of years. Recognizing that Japan has about three times the seismicity of the United States, one could make a comparative case for our research budget being about $200M per year. The Chinese spend considerable amounts of money also, but not really on very productive research activities such as those conducted in Japan and in the United States. Their problem is viewed as principally political.

Nevertheless, the United States financially lags these two countries by a considerable amount. Further, the Japanese are trading on their

earthquake engineering prowess in order to compete for construction projects in the marketplace around the Pacific Rim.

Therefore, the research budget must be examined, not simply from the loss side but from a number of other perspectives that influence the United States' ability to compete in the world market, evolve and update their cities, and provide loss control for hazards other than earthquake.

Long range implications of the budget:

I note in the National Hazards Earthquake Reduction Program, prepared by FEMA, USGS, NSF and NBS, that the budget is expected to grow from $67M to about $77M in FY 89. This would result in about a 10% gain within five years. But, considering an average inflation rate of between 4-5% and an average GNP growth rate of between 4-5%, we would actually find the Earthquake Hazards Reduction Program being reduced in real dollars by 32% over those five years. In view of my previous comments, I think this reduction is unwise.

I realize that the government is faced with serious deficits, both in the preceeding and future years. However, I can assure you those deficits will grow even further should there be a major earthquake with all of its severe consequences. Thus, this program can be viewed as a long term deficit reducing effort.

Appropriateness of the distribution of funds to meet the goals of the National Earthquake Reduction Program:

I have noted that there are five major program areas in which the funds are to be expended. These are:

- seismic design and engineering research - $25.9M (or 37% of the program)
- hazard delineation and assessment - $13.5M (or 19% of the budget)
- fundamental seismological studies - $13.4M (or 19% of the budget)
- earthquake prediction research - $12.8M (or 18% of the budget)
- preparedness planning and hazard awareness - $4.1M (or 6% of the program)

I have estimated that about $37M is aimed at the mission, or mitigation, and about $33M is directed towards research to guide that mission. This seems to be a proper balance to me. However, the balance of work for the agencies is unacceptable.

I note that the National Bureau of Standards, Center for Building Technology is given no role in the program from 1986 on. I believe this to be a serious error for the following reasons:

1. The National Bureau of Standards is the principal link between the research engineering community and the design practices. Codes in and among themselves don't mitigate a thing. There also must be design practices, construction practices, and administrative practices that accompany the codes. Further, codes are built by volunteers, many of whom are pushing their own materials or methods funded by their companies or organizations. They, for the most part, do not have the overall national perspective in view. Only the National Bureau of Standards has this national engineering perspective ranging from research on the one hand, through design and administration and construction to quality control on the other. Remember - earthquakes don't kill people. For the most part, it is the engineered or carpentered works of man that fail and fall on people causing deaths and injuries.

2. The Center for Building Technology has a host of highly-qualified engineers, many of whom are nationally prominent in their professional fields. To eliminate the activities of these people from the Earthquake Hazards Reduction Program, therefore, would be a serious loss that could not easily be regained.

3. Many of the National Bureau of Standards engineers are involved heavily in international professional organizations aimed at mitigating earthquake and other hazards. This can only bring synergism into this country. I have worked with Yugoslavians, for example, and found them to be very creative and have a number of good ideas which I have brought home to the United States. But without an authoritative, functional base such as the National Bureau of Standards, 99.9% of my reports about such matters, like most research reports, simply sit on the shelves of other researchers. However, the weight of the Bureau can bring international information into the U.S. arena.

4. Unbeknownst to many people, the National Bureau of Standards is the only engineering research facility within the federal government aimed at the construction industry. This industry, which represents almost one-tenth the Gross National Product, is tremendously fractured. To expect that private industry will take up the role of the Center for Building Technology in the earthquake program is not only wishful thinking, but it is also impossible. There is no General Motors of the construction industry. There are, of course, large companies who either build glass or make steel or make wallboard. But none of them look at the composite structure, which is made up of all these materials, in order to take research knowledge from universities, link them together and put them into practice for composite construction of buildings, bridges, highways and the like.

5. Like the NASA Research Laboratories in the space business, the National Bureau of Standards stands as the single and sole organization of its kind within the federal government. How would Boeing, alone, have put a man on the moon? How would North American Rockwell, alone, put the recoverable shuttle into orbit? Only through cooperative research and engineering between government and private practice, as well as universities, were these feats accomplished. In my opinion, the Earthquake Hazards Reduction Program will be seriously hampered if the National Bureau of Standards does not continue, not only to be involved, but to have a larger role in the engineering design and analysis work that must take place if we are truly going to mitigate earthquake hazards.

Differences in funding levels and recommendations made in the FEMA five-year plan versus the Steinbrugge Independent Review Panel's suggested plan:

I have not had the opportunity to review the Steinbrugge Panel Report so I can make no worthwhile comments on the difference in funding levels. I would, however, like to stress the fact that, if we don't increase the budget and aim the budget squarely at mitigation, the story will end like the Fram Filter ad on TV. Therein, you buy a Fram oil filter or later on you have a broken engine. The announcer says, "Pay me now, or pay me later." I believe these words are very apt for describing this program.

Comment on the recommendations made in the National Research Council's report "Earthquake Engineering Facilities and Instrumentation":

I was a member of the NAS committee which wrote this report and, therefore, have first-hand knowledge of it.

I support Recommendation 1 which calls for an enhanced budget in the earthquake engineering program. My preceeding comments fully describe why I support the recommendation that the Earthquake Research Program be enhanced.

I also fully support Recommendation 2 which states that the federal government should undertake a program to provide definition of the types of structures that need to be tested so that we can eventually control our design to limit damage in the future.

I am in partial support of Recommendation 3 regarding experimental facilities. Viewed only in the context of earthquake engineering research, I believe it is necessary that near full-scale facilities of some type be developed (not necessarily, a large shake table).

Viewed within the entire earthquake program budget, I see other types of research having equal or higher priority regarding the goal of mitigating earthquake damage.

Thus, I support the idea of full-scale testing if viewed solely in the context of earthquake engineering. I do not support the facility if it is viewed within the larger context of the total budget wherein such a facility could drain large amounts of monies from other programs of equal or greater importance.

I fully support Recommendation 4.

I fully support Recommendation 5 that deals with our involvement with the present Japanese/American Cooperative Program.

Regarding the last Recommendation involving the test facility should it be built, being the responsibility of a mission-oriented federal agency, I fully support that recommendation. When our committee asked university researchers what kinds of tests they would perform on the full-scale shake table if it were built, there was dead silence. Designers and the Electric Power Research Institute, on the other hand, had a number of questions they wanted answered. Consequently, I believe this highly-expensive test facility should be aimed at the mission, namely mitigation, of the Earthquake Hazard Reduction Program and not the research element.

Comment on any other issues:

There are many avenues for mitigation at the federal level which have received little attention to date - earthquake engineering is important, and I am an engineer. Seismology and geology research is important and I have been involved heavily with both areas. The idea of mitigation, however, in my opinion, has achieved very little attention to date.

In 1981 my firm completed a $120,000 study for the Federal Insurance Administration regarding what administration's involvement in the earthquake insurance program should be, if any. The conclusions of our report were misinterpreted, since, in fact, we had no conclusions. We only listed a series of alternatives. We wanted to conduct a workshop which would rank order the conclusions using a number of interested and affected parties; however, the Office of Management and Budget would not allow the expenditure of $16,000 additional to conduct the workshop, since, as I was told, anything that smacks of government regulation is not to be funded. I highly support the notion that there have been many regulations passed in the 1970's which were not cost beneficial. That does not mean that you throw the baby out with the bath water. The issue of earthquake insurance could be a very important mitigating tool in the Earthquake Hazards Program. And, it would require no new tools.

Today, the Federal Deposit Insurance Corporation, the Federal Savings and Loan Insurance Corporation, the VA, the FHA, the Internal Revenue Service and many other Federal organizations carry with them a large degree of statutory authority wherein they could require earthquake insurance on monies insured or guaranteed. The IRS could allow as deductible items those monies that are spent on rehabilitation or earthquake insurance. In other words, there are many "carrots and sticks" that the federal government can provide today towards earthquake hazards mitigation which require little research other than the socio-economic consequences.

It is important to conduct the types of research that are proposed in the FEMA, NSF, NBS, USGS document. However, there are other areas for research and implementation that should be studied and budgets augmented. It is in the area of public and fiscal policy that I am speaking. If the Act truly is a mission to mitigate earthquake loss, rather than fund research that carries with it the hope that mitigaton will result, I suggest that the social, public policy and fiscal policy areas be seriously addressed so that we can proactively begin the earthquake mitigation program now.

March 21, 1985 C-85-278-JHW

Congressman Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Congressman Walgren:

I have had an afterthought after my testimony yesterday regarding the argument given in the testimony of Mr. Raymond G. Kammer, Deputy Director, National Bureau of Standards, regarding the Office of Management and Budgets' reasoning for zeroing out the Center for Building Technology. He gave as a reason that the state and local governments have primary responsibility for building and safety codes. Thus, the federal government should not be involved.

This conclusion is in error for the following reasons:

1. Whereas it is true that the states and the local governments have the responsibility for building codes, earthquake damage and the mitigation of same has inter-state consequences. Namely, the consequences of an earthquake go beyond state boundaries, thus, the federal government must be involved.

2. The defense of the United States is dependent upon the ability of certain defense contractors to perform their business. If earthquakes knock them out, this seriously hinders the ability of the federal government to conduct its primary responsibility which is to defend the United States. Even though defense contractors' factories are built to local building codes, it is incumbent upon the total scenario of services - gas, water, electricity, telephone, etc. - as well as building codes to keep the defense posture intact after an earthquake.

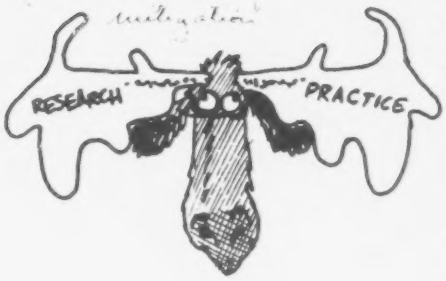
3. States outside of California are notorious for not including the earthquake provision in their building codes. For example, Ohio adopted by reference the provisions of the Uniform Building Code, but intentionally omitted the adoption of Section 2314, therein, which is the only section that has to do with earthquake protection.

Added to my earlier testimony about the Center for Building Technology's importance and roles, especially in the Earthquake Hazards Reduction Program, their involvement directly affects the defense of the nation, directly influences the fiscal posture of the nation, and does not influence a simple building code which is the state's or local government's responsibility.

Sincerely yours,

John H. Wiggins
Senior Scientist

JHW:nt



ALASKA EARTHQUAKE MITIGATION STUDY RELEASED

Following the great Alaska earthquake of 1964, the National Academy of Sciences sponsored an extensive investigation into all aspects of that disaster. The findings and recommendations of that study fill eight volumes. Corresponding with the twentieth anniversary of that earthquake, researchers at the University of Alaska and at Urban Regional Research, a consulting firm in Seattle, undertook a study, sponsored by the National Science Foundation, to assess the degree to which the recommendations of the earlier investigation had been implemented. Their recently published report, ***Seismic Hazard Mitigation: Planning and Policy Implementation, The Alaska Case*** concludes that

> if a major earthquake were to occur today the state would be no better prepared than on March 27, 1964. Measures which might have been taken to reduce the dangers from earthquakes and tsunamis have not been taken or have only been partially or imperfectly instituted. Furthermore, lands designated high risk have been developed for all uses.

The researchers found that most of the research recommended by the original study had been undertaken, but interviews with planners and administrators throughout southeast Alaska and land use analyses of the area indicated that the recommendations resulting from the research are rarely put into practice. Persons interviewed were pessimistic about the prospects of improved mitigation efforts, and cited specific impediments such as technical geological issues, land use allocations, government organization, and planning and management problems. The researchers, however, state:

> The critical obstacles to implementation of risk mitigation in Alaska are organizational and political. Organizational obstacles include imperfect scientific information and defective theoretical approaches, ambiguous policy directives, dominance of the "rational actor" model of decision making, and the difficulty of sustaining interest in the issue over time. Political obstacles to mitigation are broader and more difficult to specify and yet probably are more important. They include leaders lacking knowledge, sympathy, or commitment to implementation, aspects of the political culture—pluralistic and elite politics—and inadequate definition of the government level responsible for mitigation.

The authors argue that a comprehensive planning model incorporating a "risk" component as an integral part of the process must be used to resolve some of these basic problems, and they present such a model. They also make a strong argument for an integrated approach involving all levels of government, and conclude their work with several recommendations for programs and institutions to mitigate earthquake hazards more effectively. The well appointed volume has many excellent photographs and other informative graphics, as well as a comprehensive bibliography.

A summary of ***Seismic Hazard Mitigation: Planning and Policy Implementation, The Alaska Case*** is available free, and individual copies of the complete volume are available for $20.00 from *Urban Regional Research, Suite 200, 616 First Avenue, Seattle, Washington 98104, (206) 624-1669.*

NEXT BEST THING TO BEING THERE

For those of you who have imagined the hazard thrill of your life to be standing one day on a tall cliff and happening to see a tsunami as it rolls in from Kamchatka-Kuril—as have some individuals in our acquaintance—we may have the perfect substitute. ***Tsunamis in the Pacific Basin, 1900-1983,*** is an eye-catching 43"x 60" wall map that shows the locations of 405 earthquakes, volcanic eruptions, and landslides that caused tsunamis in this century, and indicates the size of each tsunami's runup at its point of arrival.

Produced by NOAA's National Geophysical Data Center, with support from USAID's Office of Foreign Disaster Assistance, the map uses a color-size symbol system to show the size of generating earthquake or volcanic eruption and runup height. The events are numbered and keyed to a table that lists dates and other parameters; earthquakes of magnitude R7.5 or greater that did not cause tsunamis are also noted. A second table gives statistics on tsunami casualties and property losses, and map insets detail events in Hawaii and Japan.

Tsunamis in the Pacific Basin is available for $12.00 folded ($14.00 outside the U.S.) or $20.00 rolled in a mailing tube (not available outside the U.S.) from the *National Geophysical Data Center, NOAA, Code E/GCX2, 325 Broadway, Boulder, CO 80303, (303) 497-6607.* U.S. Department of Commerce Regulations now require prepayment on all non-federal orders.

BIOGRAPHY

John H. Wiggins, is founder of the J.H. Wiggins Company, a wholly owned subsidiary of National Technical Systems and a firm specializing in Engineering Risk Assessment. He is also a consulting Professor at Stanford University. Formal education includes a B.S. in Physical Sciences from Stanford University, an M.S. in Geophysics from St. Louis University and a Ph.D. in Civil Engineering from the University of Illinois. He is a registered Civil Engineer, Safety Engineer and Geophysicist in the State of California and is a Certified Professional Geological Scientist. He holds or has held memberships of fifteen technical societies, holds three patents and has written over one hundred papers, reports and books on nuclear weapons effects, oil well drilling technology, earthquake and other natural hazards, sonic boom, insurance studies and related fields.

He has served as technical director of the National Sonic Boom Program conducted by the FAA and OSTP and has been a member of many panels and boards. He is a past member of the Building Research Advisory Board of the National Academy of Science, and has been selected by UNIDO/NSF to develop a Six Balkan Nation Earthquake Rehabilitation Manual.

In 1965, the American Society of Civil Engineers awarded him the Moisseiff Medal for earthquake engineering research contributions.

Dr. Wiggins' special interests lie in the area of linking public and corporate policy together with Risk Analysis and Decision Theory.

Mr. WALGREN. Thank you very much, Dr. Wiggins.

I want to say that all of your presentations have been very helpful in filling out a record of support of this program.

I wanted to give you an opportunity, if there are any areas outside the testimony that you presented directly, raised by other witnesses either in the previous panel or this panel, if anybody would like to make any concluding points, I would like to give you that opportunity.

Does anybody have something that they would want to say in response? Dr. Housner?

Dr. HOUSNER. I would like to say something about the discussion of the role of the NBS structural activities. Most countries have a very large research establishment for studying building structures. tures.

For example, in Japan they have just completed a $300 million research facility for their Building Research Institute, in Tsukuba City. This is in addition to mandated research establishments that each of the five largest construction companies carry; the largest of these has about 400 people, which I believe is 10 times the size of the corresponding NBS operation. So that Japan has a very large governmental building research institute, plus at least five private building research institutes. So, that to compare what we're doing in this country with what's being done in other countries like Japan, it's clear that we're not doing anything much in that respect.

Mr. WALGREN. Do we get any real direct access to their work?

Dr. HOUSNER. Not really. There is a big problem in the language. We've tried to arrange for translations of significant reports that they've put out, by having American Japanese do it. But the language is so difficult, apparently, that you just can't translate it into English satisfactorily.

Mr. WALGREN. They would claim that they try to make these available in English.

Dr. HOUSNER. Yes. The results of some of their work does come out in English language papers, for example, at the world conference, but these are selected bits of research that they publish and when we see them.

Mr. WALGREN. Yes.

Dr. HOUSNER. It's very difficult to get information from countries like Japan or China. From New Zealand it's much easier.

Mr. WALGREN. Other comments, Dr. Olson?

Dr. OLSON. Just one. The international discussion here brings up one aspect of social science research which I had neglected to mention, and that has to do with we have carved out in some ways a unique niche, in that a number of our colleagues in Japan, South America, the Caribbean—those are the areas I know best—really find it remarkable that we have social scientists working with and within an engineering program. They have had trouble bridging the gap in their own countries between policy people, social science people on one hand and the engineering and geoscience community on the other.

And they remarked to me a number of times that they find it unique and a tremendous advantage, and all I did, of course, was

smile and say, "Yes, it is a real advantage. We do have some drawbacks."

But they do find it, in a sense, unique and give us something of a leadership position because of our integration with the engineering and geoscience communities.

The other side of it is it's a little easier, I think, for us to exchange data, especially survey data. We have been doing that with the Japanese, and last Friday the Chileans promised the raw data for 700 interviews that they did 6 days after the earthquake.

So these are the areas in which it may be easier sometimes for social scientists to do this than it is where language gets to be more of a problem is in the more technical fields.

Mr. WALGREN. Thank you.

Dr. WIGGINS. I would like to say one thing I did learn from the Japanese, the one Japanese paper, which was very interesting, and this is from Japanese economists who reported on the Earthquake Program. They showed that the gross national product growth rate of the country of Japan for a number of years, I think from 1915 through 1940 and then they showed the Quanto earthquake of 1923 that happened at the same time, and you could definitely see a dip in the whole GNP, which did not recover for 10 years.

So that is what I am saying. In our economic thing, we're grasping at trying to get these numbers on what the losses are. But actually, it will affect the GNP of the Nation. So if we're looking at deficits, why, heck, it'll add nicely to the deficit.

I would like to add something about the Japanese. You know, they only spend about, oh, $13 billion a year on defense, with 40 percent of the GNP of the United States. We spend about 5 percent of our GNP; in other words, quite a bit more. So they are dumping their money into other areas. And granted, they are spending about $1 billion a year on earthquake and their seismicity is about three to four times that of the United States, so if you discount and come down, you get almost the same number that I get. You get about $160 million a year in comparable research.

And the Chinese, you know, a lot of their money, about $500 million a year on 12 percent of the GNP of the United States, a lot of their money is spent on political things. They've got a lot of people running around telling people that they're working on the earthquake problem because the Tangshan thing that Dr. Housner talked about seriously affected the political stability of the country. So, you know, it's not a small problem.

Mr. WALGREN. Dr. Agbabian.

Dr. AGBABIAN. Yes, Mr. Chairman, I would like to make a comment on the advisability of the States participating with the Federal Government in earthquake-related activities both in research and implementation. First of all, some States are conscious of the problem, and to one degree or another there is participation. It's important to establish better lines of communication with the State agencies so that they understand the importance of the program.

But most of all, I would like to emphasize the fact that the States cannot be a substitute for the Federal Government. In other words, if there is any assumption that the States should take over the function that has been carried out so far by the Federal Government, I think that's a misconception. They have their role and the

Federal Government has its role, and it is very important that the overall program that the Earthquake Hazards Reduction Act has brought into being should continue and should increase with time.

Thank you.

Dr. WIGGINS. Not only that, this revenue sharing that is before you fellows, you know, whether you should continue it or not, you could put some strings on that, and it says, "OK, you're going to get the money, but if you do, the programs that this money are going toward should have some attention toward the earthquake matter," because it affects a lot of States.

Just think, look at New Jersey, loaded with all these petrochemical plants and everything else, you know. Are we going to read about the 1988 earthquake in New Jersey with a southerly wind toward New York City?

Mr. WALGREN. All right. Well, I have enjoyed all of your testimony personally, and I want, on behalf of the committee, to thank you very much for the effort you have put into making these presentations and building this record. It will not be lost on us as a committee. We will be interested in trying to pursue some of the directions and threads that you have given us, and so let me express our appreciation very directly to you.

Thank you very much.

[Whereupon, at 4:41 p.m., the subcommittee was adjourned.]

APPENDIX

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD

Congressional Research Service
The Library of Congress

Washington D.C. 20540

March 14, 1985

TO : House Committee on Science and Technology,
Subcommittee on Science, Research and Technology
Attention: Carrye Brown

FROM : David Cheney
Analyst in Science and Technology
Science Policy Research Division

SUBJECT : National Earthquake Hazards Reduction Program: Comparison of Different Versions of the Five-Year Plan

This memo is in response to your request for a comparison of two versions of the five-year plan for the National Earthquake Hazards Reduction Program.

BACKGROUND

Public Law 96-472 enacted on October 19, 1980 amended the Earthquake Hazards Reduction Act of 1977 to require, among other things, that the Director of the Federal Emergency Management Agency (FEMA) compile and maintain a written plan for the program. The first version of the plan, which was to cover fiscal years through 1985, was due to have been completed by September 30, 1981. 1/ No plan was published by that date. In 1982, FEMA requested that each of the Federal agencies involved in program develop and provide to FEMA long-range plans for their part of the program. 2/ These were combined into one plan

1/ P.L. 96-472.

2/ John Filson, U.S. Geological Survey, telephone interview on Feb. 2, 1985.

and FEMA appointed Karl Steinbrugge to form an independent panel to review this plan. The panel made substantial revisions to the plans put forth by the agencies and forwarded their revised version of the plan to FEMA on June 9, 1983. 3/

This version of the plan was reviewed and revised by the agencies and by the Office of Management and Budget during the remainder of 1983 and all of 1984. The final version of the plan was sent to Congress at the end of 1984. This memo compares the final version of the plan with the version produced by the Independent Review Panel.

GENERAL COMPARISON OF THE PLANS

The organization of the two plans is almost identical, and most of the text, perhaps 90 percent, is identical. However, there are several general differences:

- The Review Panel's version contains numerous recommendations on budget levels and several recommendations for the management of the program. These recommendations were deleted from the final version.
- The Review Panel's version contains two budget levels: an "A" level that "permits progress at the current rate", and a "B" level that would "make more rapid achievements possible." The Panel recommended the higher "B" level of funding. The final version contains only one level of funding, a level that on the average was slightly lower than the lower "A" funding level provided by the Review Panel.
- The Review Panel's version recommends funding levels for FY1983-1987; the final version covers FY1985-1989.
- The funding levels for the Review Panel are stated to be in constant 1983 dollars; the final version does not state what

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3/ Steinbrugge, Karl. Letter to General Louis Giuffrida, Director of the Federal Emergency Management Agency, transmitting the report of the Independent Review Panel for the National Earthquake Hazard Reduction Program. June 9, 1983.

year dollars its figures are in, but they may be assumed to be in either 1985 dollars or in current dollars. This represents a decrease in the funding in the final version of the plan relative to the Review Panel's version.

DETAILED DIFFERENCES BETWEEN THE TWO VERSIONS OF THE PLAN

In addition to these general differences, there are a number of more specific differences between the two plans. These differences which deal with management concerns and Elements I-V of the plans are discussed below in the order that they are presented in the plan.

Management Recommendations

The following recommendations for the management of the program were contained in the letter transmitting the Review Panel's version of the plan to FEMA. They were not included in the final version of the plan.

- The Review Panel recommended stronger management by FEMA.
- The Review Panel recommended that FEMA charge an overhead fee for the management of the program.
- The Review Panel recommended that FEMA appoint a strong independent advisory panel.

Element I: Hazard Delineation and Assessment

- Task 1 (Establish an Accurate and Reliable National Data Base) of Objective 2 (National and Regional Earthquake Hazards Assessment) in the Review Panel's version, was eliminated in the final plan.
- Subtask D (preparation of hazards map and a risk assessment for the Boston, MA area) under Objective 2, Task 4 in the Review Panel's version (Task 3 in the final version) was eliminated in the final plan.
- Task 5 ("Regional Ground Shaking and Ground Failure Studies") of Objective 2 of the Review Panel's plan, was eliminated in the final plan.

- The Review Panel placed "Strong Ground Motion Recording and Analysis" as Objective 3 under Element I. The final version renamed this objective "Engineering Seismology" and moved it to Element III ("Seismic Design and Engineering Research").

- The Review Panel recommended the creation of a fund of $500,000 for "Post Disaster Mitigation Studies". The final plan recommended that funding for these studies be reallocated from other programs as the need arises.

Element II: Earthquake Prediction Research

- Task 3 (Conduct Earthquake Prediction Experiments in Other Regions of the United States) of Objective 2 (Earthquake Prediction Experiments) of the Review Panel's plan was deleted in the final version.

Element III: Seismic Design and Engineering Research

- The Review Panel plan named Objective 1 "Development of Model Codes and Manuals of Practice; the final plan renames this "Development of Design Practices and Manuals". Many of the tasks also differ in the two versions of this objective. The Review Panel's version has more tasks; these have been consolidated to some extent in the final version. The tasks in Review Panels version are to prepare manuals, while tasks in the final version have the more general goal of mitigating hazards.

- Several paragraphs describing the differences between funding levels A and B for Objective 1 in the Review Panel's plan have been deleted from the final version.

- Under Objective 2: "Fundamental and Applied Research," the Review Panel version describes a special need as the early investigation of structures shaken by strong earthquakes. The final version deletes this.

- The Review Panel states that a priority for additional funds would be the installation of instrumental arrays to record excess pore pressure within soils and earth structures during and following earthquakes. This is deleted from the final version.

- The final version contains some additional language reflecting the conclusions of the the National Academy of Sciences/National Research Council report: "Earthquake Engineering Facilities and Instrumentation."

- Objective 3 (Engineering Seismology) in the final version was was in Element I of the Review Panel plan (titled Strong Ground Motion Recording and Analysis). The text of the final plan was also changed to state that some strong motion data has already been acquired.

- Objective 3 (National Earthquake Experimental Capability) in the Review Panel plan became Objective 4 in the final version and was renamed "Evaluation Study on a National Earthquake Experimental Capability". The text was changed to reflect the NAS/NRC report on Earthquake Engineering Facilities and Instrumentation.

Element IV: Preparedness Planning and Hazard Awareness

- Under this element there are a few minor changes to reflect work that has been done in the two years between the two versions of the plan.

- Under Objective 3 (State and Local Preparedness Planning), the tasks have been changed considerably, in part to reflect progress in the Southern California Earthquake Preparedness Project. Task 1, 2, and 3 of the Review Panel plan (Continue the Southern California Earthquake Preparedness Project (SCEPP), San Francisco Bay Area Project, and Vulnerability Study for San Diego) are consolidated in Task 1 (California Earthquake Preparedness Project) in the final version of the plan.

- Under Objective 5 (Earthquake Education and Information Transfer) some of the tasks have been reorganized.

- Under Objective 6 (Societal Response Research) all discussion of funding levels is omitted.

Element V: Fundamental Studies

- Very few changes in this element, except to delete funding recommendations.

Appendices

- The Review Panel's plan contained Appendices on the Nuclear Regulatory Commission's Earthquake-Related Studies and the National Aeronautics and Space Administration's Geodynamics Program. These appendices were not included in the final plan.

Budget Levels

Enclosed are tables comparing the "A" and "B" budget levels of the Review Panel's version of the plan with the budget levels of the final plan.

Analysis

The most significant changes between the two versions of the plan appear to be in the budget levels. The total budget level of the final plan is much lower than the "B" level that the Independent Review Panel recommended and is significantly lower than the Review Panel's "A" budget level when inflation is considered (1986 dollars are worth about 12 percent less than 1983 dollars). Because the goals and the tasks are largely the same in each version of the plan, the effect of the lower funding levels is to stretch out the work over a longer period. As a consequence, the reduction in public exposure to the hazards accompanying earthquakes would also take longer to accomplish.

The budget levels for individual objectives of the program vary more than the totals vary. It is difficult to assess the significance of changes in budget level for any objective because the final version of the plan does not discuss why the budget levels were changed from those in the Review Panel's version of the plan.

We hope this information is useful to you, and if we can be of any further assistance, please do not hesitate to call me at 287-7017.

Enclosures

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Comparison of Budgets Recommended by the Independent Review Panel and the Final Version.
(Thousands of dollars*)

Program Element	FY 83 (actual)	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89
I. Hazard Delineation and Assessment							
Ind. A	16,202	15,510	16,086	16,466	16,466		
B		22,020	21,916	23,600	23,600		
Final			14,481	13,503	13,847	14,181	14,502
II. Earthquake Prediction Research							
Ind. A	14,460	10,390	10,800	10,800	10,800		
B		16,400	17,700	21,400	25,100		
Final			14,629	12,805	13,131	13,447	13,752
III. Seismic Design and Engineering Research							
Ind. A	16,200	22,665	25,500	23,925	21,525		
B		34,400	37,400	36,000	33,500		
Final			24,753	25,875	26,768	27,763	28,704
IV. Preparedness Planning and Hazard Awareness							
Ind. A	4,378	4,800	5,050	5,150	4,125		
B		7,400	7,000	6,750	6,250		
Final			3,915	4,129	4,471	4,674	4,886
V. Fundamental Studies							
Ind. A	11,163	12,450	13,350	14,250	15,250		
B		19,900	21,600	24,000	21,800		
Final			13,100	13,345	13,839	14,319	14,779
NEHRP Totals							
Ind. A	62,403	65,815	70,786	70,591	68,166		
B		100,120	105,616	111,750	110,250		
Final			70,518	69,657	72,056	74,384	76,623

Ind. A = "A" budget level from the Independent Review Panel plan.
B = "B" budget level from the Independent Review Panel plan.
Final = budget figures from the final NEHRP five year plan.

* Ind. A & B figures are in 1983 dollars. Final figures are in 1985 or current dollars. $100 (1983) = about $112 (1986).

Program Element I: Hazard Delineation and Assessment
(thousands of dollars)

Objectives	FY 83 (Actual)	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89
Regional Monitoring and Earthquake Potential (1) (USGS)							
Ind. A	8,002	6,290	6,116	6,116	6,116		
B		8,400	8,516	9,400	9,400		
Final			8,702	7,611	7,805	7,994	8,175
Earthquake Hazards Assessment (USGS)							
Ind. A	5,220	5,520	6,770	7,150	7,150		
B		8,620	8,900	9,700	9,700		
Final			5,779	5,892	6,042	6,187	6,327
Strong Ground Motion Recording & Analysis (2)(moved to program element III in final plan)							
Postdisaster Mitigation Studies (FEMA)							
Ind. A (3)	—	500	—	—	—		
B		500	—	—	—		
Final (4)	—	—	—	—	—	—	—
Totals (without Strong Ground Motion Recording and Analysis)							
Ind. A	13,222	12,310	12,886	13,266	13,266		
B		17,520	17,416	19,100	19,100		
Final			14,481	13,503	13,847	14,181	14,502

Notes:

(1) The title for this Objective in the Independent Review Panel plan was "Current Tectonics and Earthquake Potential".

(2) The Review Panel placed this objective under element I, while the final version places it in element III and renamed it "Engineering Seismology". The budget figures are listed under element III.

(3) The Review Panel recommended a $500,000 "no-year" fund to be used when earthquakes occur.

(4) The final plan states that funds will be allocate from existing resources as events warrant.

Program Element II: Earthquake Prediction Research
(thousands of dollars)

Objectives	FY 83 (actual)	FY 84	FY 85	FY 86	FY 87	Fy 88	FY 89
Precursor Evaluation and Prediction Methodology (USGS)							
Ind. A	3,050	1,700	1,800	1,800	1,800		
B		3,000	3,100	3,350	3,600		
Final			5,381	4,584	4,700	4,814	4,923
Earthquake Prediction Research (USGS)							
Ind. A	6,970	6,080	5,960	5,960	5,960		
B		7,500	8,500	11,000	12,000		
Final			5,760	5,976	6,128	6,275	6,418
Theoretical, Laboratory and Fault Zone Studies (USGS)							
Ind. A	3,240	1,860	1,900	1,900	1,900		
B		4,400	4,500	5,250	7,500		
Final			2,616	1,714	1,758	1,800	1,841
Induced Seismicity (USGS)							
Ind. A	1,200	750	1,140	1,140	1,140		
B		1,500	1,600	1,800	2,000		
Final			512	531	545	558	570
Totals							
Ind. A	14,460	10,390	10,800	10,800	10,800		
B		16,400	17,700	21,400	25,100		
Final			14,269	12,805	13,131	13,447	13,752

Program Element III: Seismic Design and Engineering Research
(thousands of dollars)

Objectives	FY 83 (actual)	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89
Development of Design Practices and Manuals (FEMA, NBS) (1)							
Ind. A	1,300	1,665	2,000	1,925	1,925		
B		5,900	6,300	5,400	4,700		
Final			2,399	2,030	2,735	2,820	2,886
Fundamental and Applied Research (NSF)							
Ind. A	14,900	18,000	18,500	19,000	19,600		
B		24,000	25,600	27,600	28,800		
Final			16,500	17,845	18,612	19,357	20,073
Engineering Seismology (2) (NSF)							
Ind. A	2,980	3,200	3,200	3,200	3,200		
B		4,500	4,500	4,500	4,500		
Final			3,104	3,158	3,239	3,317	3,392
Modernization of Existing Research Facilities (NSF)							
Ind. A	—	3,000	4,000	3,000	--		
B		3,000	4,000	3,000			
Final			2,000	2,092	2,182	2,269	2,353
Evaluation Study on a National Earthquake Experimental Capability (3) (FEMA)							
Ind. A	--	--	—	--	--		
B		1,500	1,500	--	--		
Final			750	750	--	--	--
Totals (4)							
Ind. A	19,180	22,865	28,700	27,125	24,725		
B		38,900	41,900	40,500	38,000		
Final			24,753	25,875	26,768	27,763	28,704

Notes:

(1) The Review Panel's title for this objective was "Development of Model Codes and Manuals of Practice."

(2) In the Review Panel's plan this objective was under Element I and titled "Strong Ground Motion Recording and Analysis."

(3) In the Review Panel's plan this objective was titled "National Earthquake Experimental Capability."

(4) These budget figures differ from those in the Review Panel's plan because they include "Engineering Seismology."

Program Element IV: Preparedness Planning and Hazard Awareness
(thousands of dollars)

Objectives	FY 83 (actual)	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89
Earthquake Hazard Mitigation Strategies (FEMA)							
Ind. A	—	--	—	--	--		
B		100	150	200	250		
Final			100	110	125	140	150
Federal Response Planning (FEMA)							
Ind. A	275	—	—	--	--		
B		350	350	300	300		
Final			350	350	365	380	394
State and Local Preparedness Planning (FEMA)							
Ind. A	1,595	1,550	1,400	1,450	425		
B		2,450	1,650	1,350	800		
Final			2,000	2,100	2,200	2,300	2,400
Multihazard Preparedness Planning (FEMA)							
Ind. A	—	500	500	500	500		
B		750	750	750	750		
Final			250	270	305	330	350
Earthquake Education and Information Transfer (FEMA)							
Ind. A	408	350	650	600	500		
B		750	1,000	950	750		
Final			355	357	494	503	533
Societal Response Research (NSF)							
Ind. A	2,100	2,400	2,500	2,600	2,700		
B		3,000	3,100	3,200	3,400		
Final			860	942	982	1,021	1,059
Totals							
Ind. A	4,378	4,800	5,050	5,150	4,125		
B		7,400	7,000	6,750	6,250		
Final			3,915	4,129	4,471	4,674	4,886

Program Element V: Fundamental Seismological Studies (1)
(thousands of dollars)

Objectives	FY 83 (actual)	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89
Implications of Plate Tectonics (NSF)							
Ind. A	3,600	4,000	4,400	4,800	5,300		
B		5,600	6,200	6,800	7,600		
Final			4,000	4,184	4,364	4,539	4,706
The Earthquake Process (NSF)							
Ind. A	3,900	4,300	4,400	4,800	5,300		
B		5,300	5,800	6,500	7,000		
Final			4,400	4,602	4,800	4,992	5,177
Earthquake Data and Information Services (USGS)							
Ind. A	3,663	4,150	4,150	4,150	4,150		
B (2)		9,000	9,600	10,700	7,200		
Final			4,700	4,559	4,675	4,788	4,896
Totals							
Ind. A	11,163	12,450	13,350	14,250	15,250		
B		19,900	21,600	24,000	21,800		
Final			13,000	13,345	13,839	14,319	14,779

Notes:

(1) In the Review Panel's plan this element was called "Fundamental Studies."

(2) The "B" budget figures include starting a National Digital Seismographic Network.

01-Mar-85

NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM
STATE FUNDING HISTORY
STATE AND LOCAL PREPAREDNESS PROJECTS

STATES	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	TOTAL
ALASKA			75000	28000	116000		100000					319000
ARKANSAS**					10000	3000	31281					44281
CALIFORNIA*	0	300000	500000	250000	650000	775000	1000000	0	0	0	0	3475000
SAN FRAN(BAREPP)					175000	375000	375000					925000
SAN DIEGO					25000	25000	200000					250000
S. CAL (SCEPP)		300000	500000	250000	450000	375000	93750					1968750
OTHER							331250					331250
HAWAII			40000	25000			58000					123000
ILLINOIS**					10000	3000	32000					45000
INDIANA**					10000		28000					38000
KENTUCKY**					10000		32000					42000
MASSACHUSETTS		100000			108000	102000	65000					375000
MISSISSIPPI**					10000		28000					38000
MISSOURI**					10000		94750					104750
NEW YORK							65000					65000
PUERTO RICO					15000	9000	62500					86500
SOUTH CAROLINA				46000		64000						110000
TENNESSEE**					10000	13000	29300					52300
UTAH			17000	25000		29962	33455					105417
VIRGIN ISLANDS					10000	41000	27500					78500
WASHINGTON		5000	60000	35000	96000	120000	125000					441000
TOTAL	0	405000	700000	409000	1063000	1157962	1803786	0	0	0	0	5542748
												0
												0

* CALIFORNIA FIGURES REFLECT TOTAL OF 4 SUBELEMENTS
** 7 STATES COMPRISE THE CENTRAL U.S. EQ PREPAREDNESS PROJECT. AMOUNTS IN THIS TABLE REFLECT STATE SPECIFIC FUNDING. AN ADDITIONAL $1,284,000 HAS BEEN ALLOCATED IN MULTI-STATE PROJECTS.

Workshop Listing

Workshops that have been held throughout the United States with funding support from the Federal Emergency Management Agency include:

1. Knoxville, Tennessee, on "Preparing for and Responding to a Damaging Earthquake in the Eastern United States," (Conference XV), September 16-18, 1981.

2. St. Louis, Missouri, on "Continuing Actions to Reduce Losses from Earthquakes in the Mississippi Valley Area," (Conference XVIII), May 24-26, 1982.

3. Charleston, South Carolina, on "The 1886 Charleston, South Carolina Earthquake and its Implications for Today," (Conference XX), May 23-26, 1983.

4. Boston, Massachusetts, on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in the Northeast," (Conference XXI), June 13-15, 1983.

5. Little Rock, Arkansas, on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in Arkansas and Nearby States," (Conference XXIII), September 20-22, 1983.

6. San Juan, Puerto Rico, on "Geologic Hazards in Puerto Rico," (Conference XXIV), April 4-6, 1984.

7. St. Thomas, Virgin Islands, on "Earthquake Hazards in the Virgin Islands Region," (Conference XXV), April 9-10, 1984.

8. Salt Lake City, Utah, on "Evaluation of Regional and Urban Earthquake Hazards and Risk in Utah," (Conference XXVI), August 14-16, 1984.

9. Albany, New York, on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in New York and Nearby States," December 12-14, 1984.

10. "Management of Earthquake Hazards in New England," November 8-9, 1984.

(Workshops 1-9 have been co-funded with the U.S. Geological Survey).